

Krapina 1: A Juvenile Neandertal From the Early Late Pleistocene of Croatia

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KEY WORDS Neandertals; craniofacial ontogeny; hominid evolution; growth and development

ABSTRACT The juvenile A Skull from Krapina, Croatia (Krapina 1) has been the subject of considerable debate since B. Škerlj first suggested that it might not be a Neandertal. Although widely known by its original designation, the Krapina A Skull was recatalogued, along with all of the Krapina hominids, in the 1980's (Radovčić, et al., [1988]. *The Krapina Hominids: An Illustrated Catalog of Skeletal Collection*. Zagreb; Mladost). It is now catalogued as Krapina 1 in the archives of the Hrvatski Prirodoslovni Muzej, Zagreb, Croatia. We present a detailed, morphometric analysis of this specimen, comparing it to other Krapina specimens, juvenile late Pleistocene hominids (including Neandertals), and subadult recent humans. This analysis demonstrates that Krapina 1 possesses morphological features that are primitive retentions; others that represent derived Neandertal specializations; and still others that are typical for all European late Pleistocene humans. Morphological features associated with the browridges are intermediate between Neandertal and early modern European form. Nevertheless, a thorough analysis of the morphology of this specimen, in ontogenetic and regional contexts, leads to the conclusion that it cannot be excluded from the Neandertal range of variation. We conclude that the most parsimonious explanation for this 130 ka specimen is that it should be regarded as a Neandertal. *Am J Phys Anthropol* 111:393–424, 2000. © 2000 Wiley-Liss, Inc.

Hušnjakovo (Hušnjak Mountain) rock shelter, usually referred to as Krapina after the village next to which it is located, is situated in the Republic of Croatia, approximately 42 km northwest of Zagreb. The site was excavated from 1899 to 1905 under the direction of the Croatian paleontologist Karl (Dragutin) Gorjanović-Kramberger, who conducted the initial analyses of the site and its contents. Krapina has proven to be the richest of all currently known early late Pleistocene sites, having yielded a huge

assemblage of Mousterian tools and débitage, an extensive collection of Upper Pleistocene fauna, and the largest number of Neandertal remains ever recovered from a single site.

The deposits at Krapina were highly stratified. Gorjanović believed they were laid down

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Received 29 May 1997; accepted 10 October 1999.

in close succession, representing a period of perhaps no more than 8,000 years, within a single climatic interval (Gorjanović-Kramberger, 1913). In the 1970s and 1980s, the geology was reinterpreted by the late Mirko Malez of the former Yugoslav Academy of Sciences (Malez, 1970a,b; 1978). Malez argued, in contrast to Gorjanović's interpretation, that the Krapina deposits spanned a long temporal interval from the Riss/Würm interglacial through Würm II stadial. This scheme was widely accepted during the 1970s and 1980s, so that studies of the Krapina material during those years often used Malez's temporal context in interpreting the hominid remains. However, subsequent ESR and U series dates on tooth enamel from numerous positions within the site yielded a mean age of 130 ± 10 ka for all the fluviatile deposits of the hominid-bearing sequence (Rink, et al., 1995). Follow-up dating has placed all of the Krapina levels between 110 and 137 ka (Rink, et al., 1999), confirming Gorjanović's original notion that the site represents a relatively short temporal span.

The date of 130 ka, at the O¹⁸ Stage 5E/6 boundary, is considerably earlier than previously suspected for the site. This dating is of considerable interest to students of late Pleistocene hominid evolution, in that it changes the manner in which the morphological variability among the Krapina people must be viewed. Earlier attempts to obtain absolute dates, such as Vogel and Waterbolk's (1972) minimum ¹⁴C date of $30,700 \pm 750$ (from unprovenienced Krapina material), and estimates from Malez's faunal correlations, bracketed the strata between approximately 80,000 (level 1) and 27,000 (level 9) ka. Now, however, the morphological variation seen between remains recovered from different levels of the deposits can no longer be considered evidence of evolution over time. As a result, the morphology of the Krapina 1 cranium, which has been suggested as possibly more modern than the bulk of the clearly Neandertal individuals from deeper in the deposits (Škerlj, 1958; Wolpoff, 1980, 1999; Minugh-Purvis, 1988a,b; Minugh-Purvis and Radovčić, 1991), merits careful reanalysis in order to better understand the specimen's taxonomic affinities. This is particularly criti-

cal in view of the widely cited evidence for early modern human morphology at Qafzeh, Israel, further east along the Mediterranean rim, possibly only 10,000 years later (Schwarcz et al., 1988; Valladas et al., 1988). Moreover, at this date, the extensive Krapina sample offers a window on the time interval prior to the appearance of the so-called "Classic" Neandertal morphology in Western Europe and following the appearance of pre-Neandertal peoples such as those represented by the Atapuerca hominids (Arsuaga, et al., 1993).

STRATIGRAPHY, ARCHAEOLOGY, AND KRAPINA 1

The vast majority of the Krapina hominids were excavated from levels 3 and 4, labeled the "*Homo* zone" by Gorjanović (nd; Gorjanović-Kramberger, 1906; see also Smith, 1976a, 1982), but a few were also recovered from layers 1, 2, 5, 6, 7, and 8. In Gorjanović's original stratigraphic scheme for the site, fossils and artifacts were labeled as having come from levels I, 1, 2, 3, 4, 5, 6a, 6b, or 7. However, on August 8, late in the 1900 field season, Gorjanović changed the number of recognized strata in the site from 9 to 8 levels (Gorjanović, nd; Radovčić, et al., 1988). According to his field notes, level 6a became designated as level 7 and level 6b as level 8. Gorjanović had originally grouped levels 6a and 6b together, but later separated them into two distinct levels believing each was associated with a different faunal zone. Level 7, along with 5 and 6, was designated as the *Rhinoceros mercki* zone and level 8, together with level 9, the *Ursus spelaeus* zone (Radovčić, et al., 1988). Recent reanalysis of the stone tools has established that all stratigraphic levels at Krapina yield scraper rich Mousterian assemblages, showing remarkable typological consistency (Simek, 1991; Simek and Smith, 1997). Retouched tools are concentrated in levels 3 (Gorjanović's *Homo* zone) and level 8, but lower level assemblages differ from the upper levels only in showing less selectivity in raw material selection and less efficient means for exploiting the raw materials (Simek and Smith, 1997). While these technological shifts are not unimportant, the behavioral context for the Krapina people is

fundamentally the same throughout the deposits.

One of the most complete specimens from the site is the juvenile Krapina 1 partial calvarium from level 8, generally regarded as the highest hominid-bearing stratum in the deposits.¹ Historically, Krapina 1 is the most controversial specimen from the site. This child, which has been gradually reconstructed over the years from an incomplete calotte into a partial neurocranium, is substantially different today than in Gorjanović's time (see Fig. 1) and, over the years, has been variously interpreted as a Neanderthal (Smith, 1976; Minugh-Purvis, 1998; Minugh-Purvis et al., 1996); a possible transitional specimen (Minugh-Purvis, 1988a,b; Minugh-Purvis and Radovčić, 1991; Wolpoff, 1980, 1995); and even a possible representative of early modern humans in the late Pleistocene of Croatia (Škerlj, 1958). Despite the range of opinion expressed by these authors, all have pointed out aspects of the morphology of Krapina 1 that suggest that it was not, perhaps, a typical Neanderthal (Minugh-Purvis, 1988a,b, 1998; Minugh-Purvis and Radovčić, 1991; Wolpoff, 1980, 1995; Smith, 1976). Smith (1976; Smith and Ranyard 1980) has repeatedly argued that its morphology should be interpreted cautiously, since its modern appearance could be due, in part, to its young age at death. Previous descriptions have also suggested that perhaps pathology, postmortem deformation, or both could have produced distortions in Krapina 1 that could easily be confused with a more modern morphology.

Krapina 1 has been previously described (Gorjanović-Kramberger, 1906; Smith, 1976; Minugh-Purvis, 1988a; Minugh-Purvis and Radovčić, 1991), but never exhaustively. Moreover, with the addition of numerous large fragments to the specimen since 1981, it is now obvious that neither postmortem deformation nor pathology have altered its

morphology. While the significance of the young developmental age of this juvenile on interpretations of its morphology cannot be disputed, current understanding of Pleistocene hominid craniofacial growth and development, made possible by several studies in recent years (Heim, 1982; Tillier, 1983, 1984, 1987, 1988, 1989; Madre-Dupouy, 1992; Minugh-Purvis, 1988a, 1993, 1998, and others), permits interpretation of the morphology of the Krapina 1 child with some confidence.

HISTORY OF THE RECONSTRUCTION

From the time of its original publication by Gorjanović in 1906 until 1981, Krapina 1 remained virtually unchanged, consisting of a nearly complete metopic frontal joined to anterior portions of the left and right parietals. One of us (FHS) suggested in the 1970s that an immature partial left temporal, Krapina 39.4 (Temporal #5) might belong to this same juvenile but was unable to establish any bony connections to verify this suspicion. However, in the winter of 1981–1982, and the summer of 1982, two of us (NM-P and JR) were successful in adding several large fragments to Krapina 1, including Krapina 39.4 (Temporal #5).

The key to the new reconstruction was found while searching for fragments of hominid bone that might have been overlooked by Gorjanović among the Krapina faunal remains. During this search, a partial left temporal squama was found that fit perfectly to Krapina 39.4 (Temporal #5). The two pieces, similar in coloration and bone density, share surface details crossing the 52.5 mm break along which they join. We also found a small portion of hominid parietal from the region of asterion that matched a portion of inferior left parietal assembled earlier from two unnumbered fragments. Again, similarity in pigmentation, bone density, and pitting found on the internal and external bony tables of both this parietal and Krapina 39.4 (Temporal #5) suggested that they could be the same individual. This was verified by their perfect articulation along the preserved posterior half of the squamosal suture and for 17.4 mm along

¹Although level 8 is usually regarded as the highest fossil-bearing stratum at the site, Krapina 188.6, a right immature ulnar diaphyseal fragment, was recorded by Gorjanović as coming from level 9. One of us (JR) considers this a case of confusion resulting from the renumbering of the site's stratigraphy in 1900. Krapina 188.6 was, most probably, excavated from level 8.

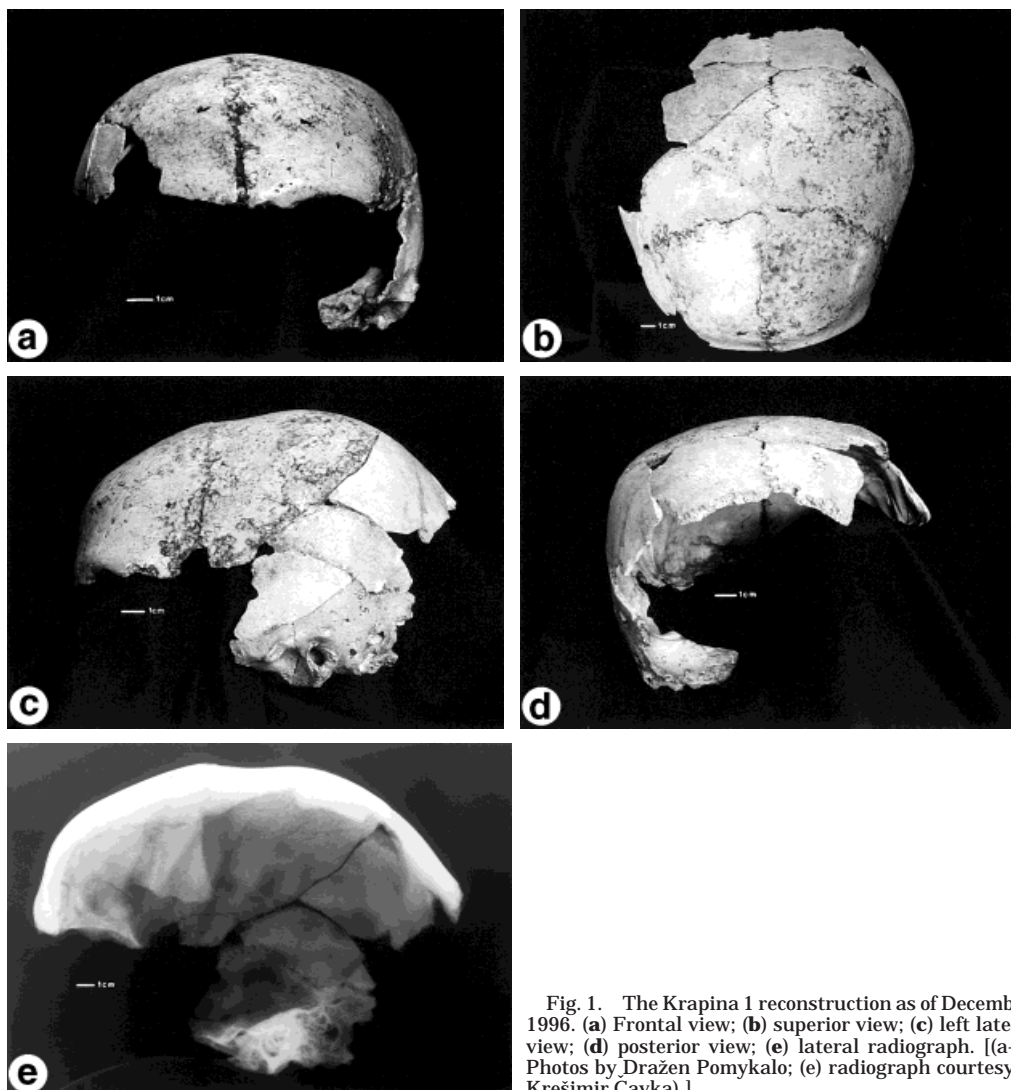


Fig. 1. The Krapina 1 reconstruction as of December, 1996. (a) Frontal view; (b) superior view; (c) left lateral view; (d) posterior view; (e) lateral radiograph. [(a–d) Photos by Dražen Pomykalo; (e) radiograph courtesy of Krešimir Čavka].

nearly the entire length of the parieto-mastoid suture as well. We subsequently fitted this parieto-temporal complex to the Krapina 1 calotte along an oblique break or cut through the left parietal, where they are in contact for 40.6 mm. In October, 1982, an additional large fragment of posterior left parietal, bearing 14.2 mm of the lambdoid suture, was identified by Mary Russell. This fragment fit into a wedge-shaped break formed along 52 mm of the original broken left posterior parietal squama and along another 27 mm break. Although different in coloration from the original Krapina A cal-

varium,² the fit is excellent, leaving no doubt this fragment belongs to Krapina 1.

The right parietal has also been further reconstructed in recent years. In 1981, a piece of unnumbered parietal was added to the posterior of the right parietal of Krapina 1 by two of us (NM-P and JR), extending that bone another 9.4 mm posteriorly along

²Several Krapina crania are reconstructed from fragments of differing pigmentation. This is not surprising, however, since many of the bones were broken and the fragments were clearly disassociated prior to excavation (Trinkaus, 1985; Gorjanović-Kramberger, 1906; Smith, 1976a; Ullrich, 1978; Russell, 1987a,b; Radović et al., 1988; Radović, 1988).

the sagittal suture. This fragment joins neatly to the posterior portion of the original calvarium along a 47.8 mm break. Here, the fragment has a similar bone thickness to the rest of the Krapina 1 parietal and provides continuity for the groove of the superior sagittal sinus endocranially. In 1988, M.H. Wolpoff and R. Caspari added three additional fragments to Krapina 1. Two of these are small pieces of right frontal, which together securely join the main section of the right frontal squama along a 31.3 mm break and extend posteriorly to a well-preserved sphenoidal articulation. Posteriorly, these two joined fragments bear 36.4 mm of the coronal suture and articulate with a fragment of right parietal also added by Wolpoff and Caspari. This small right parietal fragment, in turn, joins the main portion of the calotte superomedially along a 15.5 mm broken edge.

In 1993, T.D. White identified another isolated Krapina cranial vault fragment (Krapina 34.4) as part of the Krapina 1 child, fitting it to 36.5 mm of broken posterior left parietal. This fragment preserves 37 mm of the sagittal suture and 39.9 mm of the left lambdoid suture, and is roughly rectangular in shape measuring approximately 44×49 mm. Soon afterward, another portion of the Krapina 1 right parietal, Krapina 33.2 (previously catalogued as a frontal fragment) was found by one of us (JR) to neatly articulate with the left posterior sagittal suture. This fragment preserves some 27 mm of sagittal suture and 36.5 mm of lambdoid suture. These posterior parietal fragments extend the vault 35 mm further posteriorly to the lambdoid suture. With the addition of these fragments added since 1981, the resultant reconstruction (Fig. 1a–d) comprises a partial neurocranium, consisting of a nearly complete frontal; a virtually complete left parietal and temporal; and a partial right parietal. These additions make Krapina 1 considerably more complete than the A Skull described by Gorjanović in 1906.

PRESERVATION

Frontal

In its present state, the Krapina 1 frontal consists of the majority of the left frontal moiety that is securely articulated along a

patent metopic suture to the approximately three-quarters preserved right moiety. The frontonasal and frontolacrimal articulations, as well as the most medial aspects of the supraorbitals, are absent bilaterally, as the specimen was broken off an estimated 6 mm superior to nasion. Glabella is preserved, but frontal breadth at this position is increased by approximately 3.4 mm owing to the presence of quartz pebbles, matrix, and glue lodged in the metopic suture, thereby separating the left from right frontal halves. The metopic suture is visible both endocranially and ectocranially.

On the left, the frontal articulates with an essentially complete left parietal along 102.5 mm of coronal suture. The origin of the inferior temporal line is evident arising from behind the broken lateral portion of the left browridge. Here the lateralmost portion of the supraorbital is slightly damaged, exposing cortical bone approaching the left frontozygomatic articulation. A small portion of the left lateral orbital roof extends 23.9 mm posteriorly to form a portion of the anterior cranial fossa floor. However, the majority of the medial two-thirds of the left orbital roof and the most medial supraorbital region are absent. None of the sphenofrontal suture is preserved.

The more fragmentary right frontal moiety preserves less of the supraorbital region than does the left. The right superior portion of the browridge is well-preserved medially, but has been broken off near mid-orbit so that none of the lateral portion remains. No remnants of orbital roof are preserved on the right, and the squama immediately posterior to the lateral supraorbital region is also absent. More posterior portions of the right frontal squama are preserved, including its articulation with the right parietal along 95 mm of the coronal suture.

Parietals

The Krapina 1 mid-vault segment is quite complete, represented by major portions of both parietals separated by a fully patent sagittal suture. Preservation of both the ecto- and endocranial surfaces is, for the most part, excellent.

Although reconstructed from six fragments, the left parietal is now nearly complete, extending from the coronal to lamb-

doid and from the sagittal to squamosal sutures. However, bone is missing from: a 14.9×15.2 mm triangular area just posterior to the left parietal boss; a 13–14 mm length of posterior parietal along the lambdoid suture, which apparently included a supernumerary ossicle; and a wedge of posterior squama. This wedge includes 37.2 mm of left lambdoid suture beginning midway along the posterior parietal border and extending laterally to asterion, so that the region of asterion remains incomplete.

Anteriorly, both bregma and part of the region around pterion are preserved, as are 114.5 mm of the coronal suture. The sphenoidal articular surface for the greater wing has been preserved where it is continuous with the squamosal sutural border for 16.4 mm. Further posteriorly, another 45 mm of left squamosal suture are preserved. Of the 105 mm (arc) length of preserved posterior parietal, only about 55 mm of the medial lambdoid suture remain. The left parietal articulates firmly with the nearly complete left temporal bone. As the temporal bone is approached, surface pitting becomes quite extensive ectocranially as well as endocranially.

The right parietal has been reconstructed from six fragments, with approximately two-thirds of this bone represented. This includes 95 mm of coronal suture and the complete length of the sagittal suture (111 mm arc) and 36.3 mm of lambdoid suture, running from lambda laterally. The region of asterion and the entire squamosal border are absent. At least one supernumerary ossicle was present along the right lambdoid suture as on the left side.

Temporal

The left temporal, Krapina 39.4 (formerly Temporal #5), is nearly complete, lacking only the majority of the zygomatic process and the anterior third of the squamous portion. Fifty-two mm of squamosal suture are preserved, as are 23.3 mm of parietomastoid suture from the temporal incisure to asterion. The anteromedial petrous has experienced some breakage and external bone loss, but elsewhere on the inferior and anterior petrosal faces, damage is limited to slight surface abrasion. The petrous root

remains undamaged with excellent preservation of structural details.

Total vault

Although the original Krapina A calotte was heavily shellacked, curation of the more recently added pieces varies considerably. Shellacking the main original calotte was done without complete removal of adhering matrix. There has been some exfoliation of the endocranial cortical layer, along with its shellac, exposing a few small spots where supporting sticks were previously glued; but generally both the ecto- and endocranial surfaces are in excellent condition. Fragments located in 1981 among the faunal remains have received little treatment, while Krapina 39.4 (Temporal #5), which was curated with the hominid material but not fitted to a major specimen by Gorjanović, was only lightly shellacked.

POSTMORTEM DEFORMATION

The original Krapina 1 calotte, as reconstructed by Gorjanović, showed a clear fracture of the right parietal noted by Smith (1976), which appears to have resulted from crushing of the vault posterior and to the right of bregma. Smith (1976) attributed this damage to compression from above and cautioned, at that time, that the unusually great breadth of the specimen might be an artifact of postmortem deformation. However, recent additions to the specimen have convincingly demonstrated that Krapina 1 is accurately regarded as having a wide calvarium and that postmortem plastic deformation, if present at all, is negligible.

Many of the breaks in Krapina 1 show freshly exposed edges of bone, indicating relatively recent damage (i.e., occurring during or since excavation). However, some other breaks were clearly perimortem. Beginning a little more than 1 cm posterior to pterion, following the borders of the original Krapina A calotte, the left parietal was divided or severed transversely by an arc running through the parietal boss from the sagittal to squamosal sutures. This edge of the original calotte was completely encrusted with matrix, indicating that the specimen was probably originally interred in a few large pieces broken prior to fossiliza-

tion (T.D. White, personal communication). No specific cutmarks, suggestive of defleshing or cannibalism, have yet been reported on Krapina 1. However, White (personal communication) has observed midsagittal and coronal striations apparently caused by a craniostat needle.

AGE AT DEATH

Because of its immaturity, the accuracy of any morphological analysis of Krapina 1 depends upon its assessment within the correct ontogenetic context. This requires a reasonably accurate determination of its developmental age at death. Despite the lack of any associated dentition, a number of criteria may be considered in estimating the *probable range* of age at death for Krapina 1. These include the development of sutures, fontanelles, frontal sinus, browridge, stylo-mastoid foramen, tympanic region, glenoid fossa, and calvarial thickness.

Suture closure/bregmatic fontanelle

None of the preserved sutures (sagittal, coronal, metopic, lambdoid, mastoccipital, and squamosal) show evidence of obliteration either ecto- or endocranially. However, as observed by Smith (1976) and Minugh-Purvis (1988a,b; Minugh-Purvis and Radovčić, 1991), the metopic suture in Krapina 1 represents a persistent form of this trait and thus is not useful in determining the specimen's ontogenetic age.³

As noted by Vlček (1970), Smith (1976), and Minugh-Purvis (1988b), the Krapina 1 bregmatic fontanelle was completely closed. This feature, which normally ossifies around 2.5 years of age in modern humans (Williams et al., 1989) indicates a child well past infancy at the time of death. Moreover, this

³Although clearly beyond infancy, the the Krapina 1 frontal exhibits a fully patent metopic suture. In modern human populations, this suture commences fusion in the middle of the second postnatal year, approximately midway between nasion and bregma (Warwick and Williams, 1973). Fusion is usually complete by 3 to 4 years, although in some cases the scar is not completely obliterated until age 8 (Warwick and Williams, 1973), and the same appears to be true of Neandertal children as well (Minugh-Purvis, 1988a). With no indication of any fusion, the presence of this suture in Krapina 1 represents a clear case of metopic retention. Among modern humans, Breathnach (1965) reports the incidence of metopism as 7–10% in modern Europeans while Hauser and de Stefano (1989) report a 5% incidence of complete metopism in central European adults. This trait, which is believed to have a high heritability coefficient (Sjøvold, 1984), is also seen in Krapina 20, a fragment of adult cranial vault from an unknown level at the site (Radovčić, et al., 1988).



Fig. 2. Krapina 1 frontal sinuses, Water's view. (Radiograph courtesy of Krešimir Cavka.)

closure was not recent at the time of death, as the thickness of the vault at bregma is comparable to that elsewhere on the Krapina 1 frontal and parietal squamae (Tables 1 and 3).

Frontal sinus

Although lacking the region around nasion, the Krapina 1 frontal clearly preserves the superiormost portions of the fronto-nasal region where frontal sinus development would be in evidence. Upon radiographic examination (Fig. 2), the frontal sinuses are seen as bilateral radiolucencies, particularly in the more complete left brow-ridge. Gross examination of the specimen shows a 6 mm separation between the inner and outer bony tables approaching glabella.

Despite considerable variation in shape, pneumatization and maturational course frontal sinus development in modern humans is minimal until mid-childhood (Szilvássy, unpublished data, 1981). Ritter (1978) and Szilvássy (1981) reported sinus size upon anteroposterior radiographic examination as approximately 0.5 cm² by age 6, and Szilvássy (1981) reported that males experience

a doubling in frontal sinus size between ages 5 and 7 years, while females experience a smaller size increase between 5 and 7 years. Consistent with this correlation, Hauser and deStefano (1989) report that modern human frontal sinuses undergo a secondary expansion at first molar eruption. Nevertheless, because the most marked expansion occurs around puberty, most younger modern children do not usually exhibit pneumatization of the orbital roof nor spreading of the sinus to the frontal squama (Szilvassy, 1981 and unpublished data).

In a comparison of frontal sinus ontogeny in Neandertals, Vlček (1969, 1970) described the presence of a small pneumatized invasion of the frontal superior to the fronto-nasal suture in the La Quina 18 child and the presence of several, larger pneumatized cavities in the infero-medial frontal of the slightly older Teshik-Tash specimen. It would appear, based on radiographic examination, that frontal sinus development in Krapina 1 was comparable to that found in the La Quina 18 and Teshik-Tash 1 juveniles, aged at 7.5 and 10 years, respectively (see Fig. 3). Moreover, in modern humans, frontal sinus development correlates closely with supra-ciliary arch appearance (Weinmann and Sicher, 1955), which, in turn, begins its development at approximately the time of first molar eruption (Minugh-Purvis, 1988a). When compared with Neandertal and early modern late Pleistocene children, the clearly observable browridge present on Krapina 1 reveals just the degree of supraorbital relief expected in a child entering a mixed dentition (Minugh-Purvis, 1988a).

Tympanic region

The tympanic ring in Krapina 1 had completed its formation and was fully fused to the tympanic plate at the time of death. Weaver (1978; 1979) found that the external auditory meatus was fully formed between the dental ages of 3 and 5.5 years in an Amerind series from Grasshopper Pueblo.

The tympanic plate in Krapina 1 had also completed its formation and closed, except for a tiny persistent foramen of Huschke. According to Weaver's study, this closure occurs in modern humans by at least 4 years of age. However, utilizing an analogous degree of modern human tympanic plate matu-

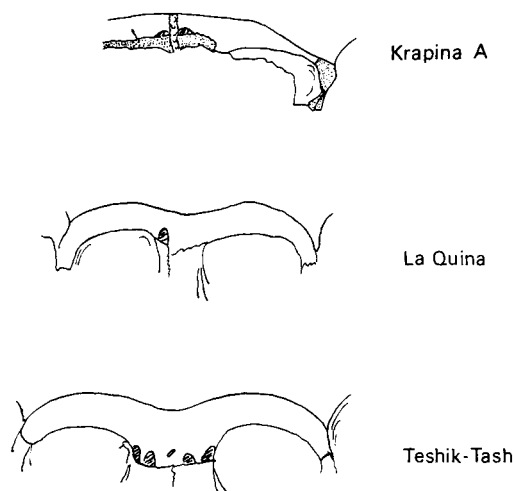


Fig. 3. Comparison of Krapina 1 frontal sinus development with Neandertal children of mid-late childhood age.

rity for age determination in this or any child of possible Neandertal affinities is questionable due to the bipartite tympanic plate that forms as a result of different developmental patterning in Neandertals as opposed to modern children (Minugh-Purvis, in preparation). Thus, while the completed formation of the tympanic ring may provide acceptable evidence of an age >3–5.5 years for Krapina 1, the developmental status of its tympanic plate should probably not be considered as an appropriate ageing criterion.

Orientation of glenoid fossa

Another aspect of temporal morphology that assists in arriving at an age range estimate for Krapina 1 is the orientation of the glenoid articular surface. This surface faces nearly 45° laterally in newborn modern humans and in young Neandertals (Minugh-Purvis, personal observation and 1988a), and attainment of a horizontal orientation of the articular surface usually occurs no later than the eighth year of life (Minugh-Purvis, 1988a). In Krapina 1, this feature appears to be very close to its mature disposition.

Position of stylomastoid foramen

The Krapina 1 stylomastoid foramen is situated completely on the basal aspect of the petromastoid portion of the temporal,

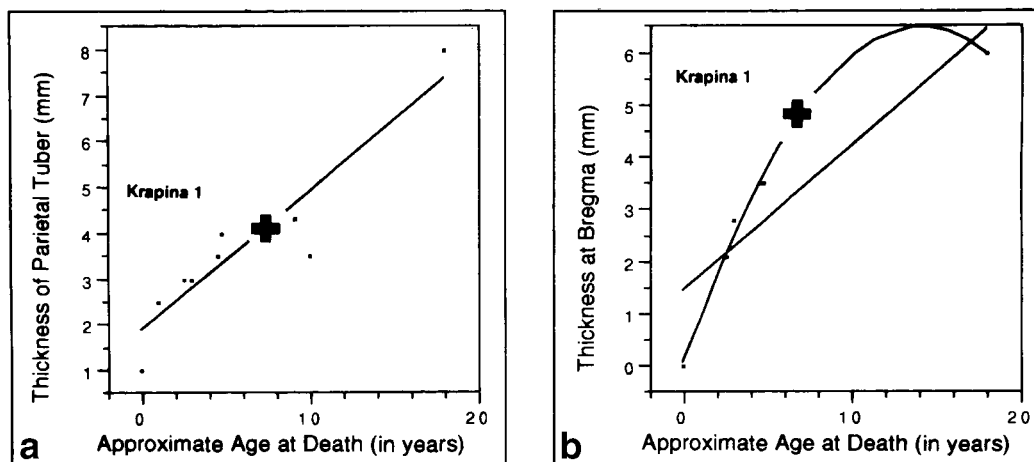


Fig. 4. Position of Krapina 1 relative to growth curves for Neandertal cranial thickness. (a) Linear fit for growth in cranial thickness at the parietal tuber ($N = 11$ values: 10 immature specimens and the adult Neandertal mean; $r^2 = 0.85631$, $P < 0.0000$). (b) Linear and quadratic fits for growth in cranial thickness at

bregma ($N = 6$ values: five immature specimens and the adult Neandertal mean; linear fit: $r^2 = 0.8064$, $p < 0.0151$; quadratic fit: $r^2 = 0.993885$, $p < 0.0005$). Note that in all plots, the Subalyuk 2 and Pech de l'Azé children occupy the same position on the graph and thus appear as a single point.

suggesting an individual well beyond infancy. This foramen, situated laterally at birth in both modern human and Neandertal infant temporals, rapidly assumes an inferior position on the basicranium as the mastoid process grows lateral to it in early childhood. In the 2.5-year-old Neandertal from Pech de l'Azé, for example, the stylo-mastoid foramen already lies superomedial to the diminutive mastoid process.

Neurocranial thickness and summary developmental age estimate

The correlation between ontogenetic increase in cranial thickness observed in Neandertal children preserving a dentition provides another method for bracketing the age at death of Krapina 1. For example, in comparing skull vault thickness at the parietal tuberosity for ten immature Neandertals and the adult Neandertal mean, a linear fit of $r^2 = 0.8563$, $p < 0.0000$ was obtained. When compared with this sample, Krapina 1 falls precisely on this line for 7-year-old Neandertals (Fig. 4a). Comparisons of thickness at bregma for five Neandertal children and the adult Neandertal mean showed a slightly poorer but still strong linear fit of $r^2 = 0.8064$, $p < 0.0151$. In addition, an excellent second degree (quadratic) polynomial fit of $r^2 = 0.9938$, with $p < 0.0005$ was

obtained using this same sample of data. When compared with this sample, Krapina 1 falls precisely on the quadratic curve for a 7-year-old Neandertal (Fig. 4b).

Based on the above criteria, our efforts to estimate the age at death of Krapina 1 seem to repeatedly arrive at a mid-childhood range, with evidence supporting a probable age at death between 6 and 8 years as originally suggested by Smith (1976).

SEX DETERMINATION

Due to the well-known difficulties involved in sexing immature skeletal remains, we have not assigned a sex to Krapina 1.

MORPHOLOGY AND GROWTH

Frontal

The well-preserved Krapina 1 frontal possesses clear frontal eminences. However, these are not as distinct, nor does the Krapina 1 forehead rise nearly as vertically to metopion as occurs in early or recent modern children of comparable developmental age. Both the glabella-metopion chord and arc are 35 mm in length, reflecting the flattened forehead typical of mid-childhood by which time the bulbous forehead of infancy is usually lost. The segment from metopion-bregma is more curved, with a

TABLE 1. *Frontal dimensions for Krapina 1¹⁻³*

Approx. age at death (years)	Krapina 1 6.0–8.0	Engis 2 4.0–5.0	Devil's Tower 4.0–5.0	La Quina 18 7.0–8.0	Teshik-Tash 1 10.0–11.0	Le Fate 7.0–9.0	La Chaise 16 juvenile	Carigüela 2 juvenile	Recent modern children ⁴ 6.0–7.9
Dimensions⁵									
M9 minimum frontal breadth	[100]	94	102.8	89.5	100.0	92.0	—	96.5	86.1 ± 4.17 (N = 22)
M10 maximum frontal breadth	121.0	115.0	125.0	108.0	120.0	—	—	[120]	104.3 ± 4.18 (N = 21)
M43 bi-stephanic breadth	[121]	105.0	125.0	107.0	118.0	104	—	120.0	97.2 ± 3.09 (N = 5)
M29 nasion-bregma chord	[98]	101.0	101.0	94.0	106.0	—	—	88.1	104.3 ± 3.1 (N = 23)
M26 nasion-bregma arc	[111]	117.5	117.0	103.5	120.0	—	—	100.0	122.0 ± 4.97 (N = 23)
Glabella-bregma chord	94.5	—	97.1	92.0	98.0	—	89.6	[83]	98.8 ± 2.5 (N = 5)
Glabella-bregma arc	108	—	105.0	100.0	105.0	—	104	[90]	116.6 ± 5.0 (N = 5)
Indices⁵									
M9/10 index of frontal broadening	[82.6]	81.7	81.6	82.8	83.3	—	—	96.5	82.5 ± 2.82 (N = 21)
M29/26 Index of sagittal frontal curvature	[88.2]	86.3	86.3	90.8	88.4	—	—	88.1	86.1 ± 3.66 (N = 23)
Index of glabella-bregma curvature	87.5	—	—	92.0	93.5	—	86.1	92.0	84.8 ± 2.48 (N = 5)

¹ All measurements in millimeters.² Metric data after Minugh-Purvis (in preparation).³ Bracketed values represent estimated measurements or indices derived from estimated measurements.⁴ Metrics recorded as the mean ± 2 SD of a combination of several samples of recent modern children of mid-childhood age at death. After Minugh-Purvis (in preparation).⁵ Where applicable, metric dimensions and indices have also been identified by Martin (1928) reference numbers.

chord of 65.4 mm and an arc of 67 mm. The metopic suture extends the entire anterior-posterior length of the preserved bone, from glabella to bregma, a distance of 93 mm. A slight mounding occurs on the posterior frontal approaching bregma, similar to that which McCown and Keith (1939) reported for the Skhul 1 child. A long groove for a branch of the supraorbital nerve scores the surface of the left frontal as it runs 45.7 mm from the mid-browridge, just lateral to the frontal tuber. On the less complete right squama, portions of similar impressions are visible.

With an estimated nasion-bregma chord length of 98 mm (see Table 1), Krapina 1 falls solidly within the Neandertal range, slightly below that of recent modern children (Table 1). However, Krapina 1 possesses a longer frontal arc length of [111 mm],⁴ falling at the recent mean as do several other Neandertal children. The in-

dex of frontal sagittal curvature of Krapina 1, at [88.2 mm], is entirely consistent with the degree of frontal curvature seen in comparably aged Neandertal and early Upper Paleolithic associated modern European children. In recent modern children, this index is usually slightly lower, indicating a more curved frontal in the latter (Minugh-Purvis, 1988a). In Krapina 1, nasion-bregma curvature is consistent with the index of frontal sagittal curvature obtained using the glabella-bregma dimension. However, the Krapina 1 glabella-bregma index of sagittal curvature is less than in either the La Quina 18 or Teshik-Tash Neandertal children due to the greater amount of anterior browridge projection at glabella in the latter two specimens (see Table 1).

Krapina 1 possesses a broad frontal typical of both archaic and modern Europeans (Table 1). When plotted against European Neandertal and early Upper Paleolithic associated modern Europeans its minimum frontal breadth of [100 mm] falls high above the

⁴Estimated values indicated by square brackets.

modern range and well within the late Pleistocene European range for this dimension. We note that it is considerably larger than both the Skhul 1 or Qafzeh 11 juveniles for this dimension (Fig. 5a). With a maximum frontal breadth of 121 mm, similar comparisons again place Krapina 1 high above the modern mean along with other European Neandertal and early Upper Paleolithic associated children. For this dimension too, Krapina 1 is dramatically larger than either the Skhul 1 or Qafzeh 11 children who fall at or below the modern human mean for maximum frontal breadth (Fig. 5b). Similar comparisons of the Krapina 1 bi-stephanic breadth [121 mm] place Krapina 1 at the upper end of the Neandertal range and well above the average for recent modern children. While these frontal breadth comparisons are not useful in distinguishing between European Neandertals and the early modern Upper Paleolithic associated Europeans who followed them in time, they do, nevertheless, strongly align Krapina 1 with other late Pleistocene Europeans for minimum and maximum frontal breadths as illustrated in Fig. 5a and b.

Anteriorly, the left browridge surmounts a well-rounded superior orbital margin of the form commonly encountered in European Neandertals. As discussed previously, frontal sinus development had begun and the outlines of small pneumatized cavities are visible at the break inferior to the browridges medially where separations between the outer and inner bony tables are readily apparent (see Fig. 2). Medially, at 10.5 to 13.2 mm from the midsagittal plane, two large and several smaller foramina, possibly conveying nutrient vessels to the developing sinuses, penetrate the medial left browridge. A canal for vessels and nerves to the left frontal sinus is broken open and part of its course visible beginning 17.7 mm lateral to the midline. Similarly, 3 large foramina are present on the right side.

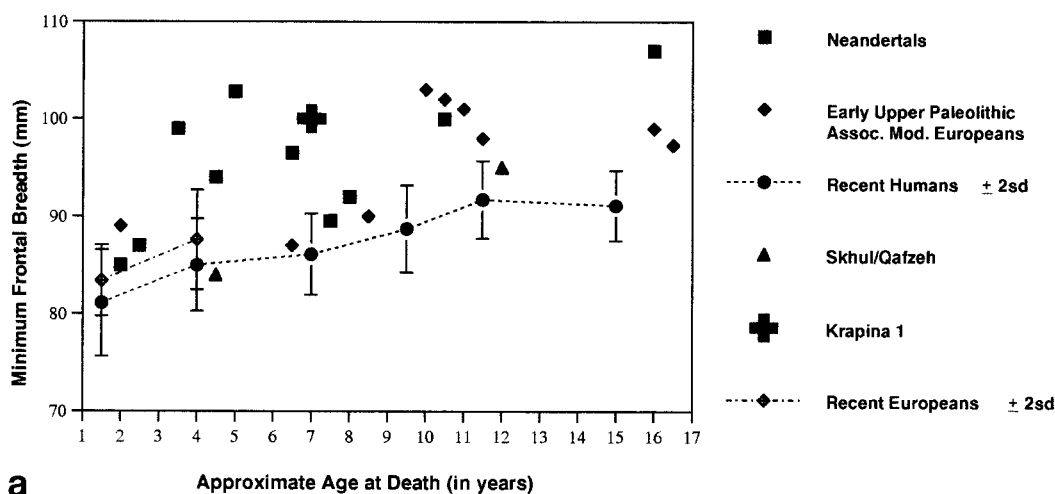
Comparative studies of Upper Pleistocene juveniles indicate that browridge *form*, although not size, is reached by approximately 2½ years of age in Neandertals and by 5–6 years in all *H. sapiens* (Minugh-Purvis, 1988a). While this structure is not yet robust in Krapina 1, its future, adult brow-

ridge *form* is clearly foreshadowed and it is unmistakable that a true supraorbital torus would have developed had Krapina 1 lived to adulthood.

Krapina 1 exhibits only very slight anteroposterior prominence of the area immediately around glabella, certainly less than what is present in the 7–7.5 year old La Quina 18 child. Viewed from the superior aspect (Fig. 1b), the glabellar portion is anterior to the lateral-most supraorbital margin as in the Le Moustier 1, La Quina 18, and Gibraltar 1 immature Neandertals. However, midline growth in anterior-posterior projection in the Krapina child was possibly inhibited by the presence of the metopic suture. Nevertheless, both Krapina 1 browridges have well-developed medial portions. Morphologically the Krapina 1 supraorbitals consist of bipartite structures divided into a medial and a lateral component (see Fig. 6) as noted by Smith and Raynard (1980). On the left, the medial portion is approximately 11.9 mm in maximum height and is easily distinguishable from the *pars lateralis*. Although the lateral portion is well developed in its anterior projection from the squama, it is only 4 mm in height (Fig. 6). This low, lateral vertical height gives the “pinched” appearance encountered in very late Neandertals such as those from Vindija, Croatia (Wolpoff et al., 1981) and Le Moustier, France (Thompson and Bilsborough, 1997) or in various central European Upper Paleolithic specimens (Smith and Ranyard, 1980).

Metrically, the dramatic difference between medial and lateral supraorbital height in Krapina 1 is obvious when compared with other juvenile Neandertals (Table 2). In this regard, the Krapina 1 supraorbitals are unquestionably different from those of all other adults and juveniles from the site. In contrast, the other Krapina frontals exhibit the typical Neandertal browridge morphology described by Le Gros Clark (1964) as constituted by a continuous bony bar of more or less uniform thickness across the supraorbital margin, and bridging glabella. Certainly a range of variation in supraorbital form is found within the Krapina sample itself, but Krapina 1 represents, by far, the most extreme case of reduction in the lateral

Comparison of Minimum Frontal Breadth in Krapina 1



Comparison of Maximum Frontal Breadth in Krapina 1

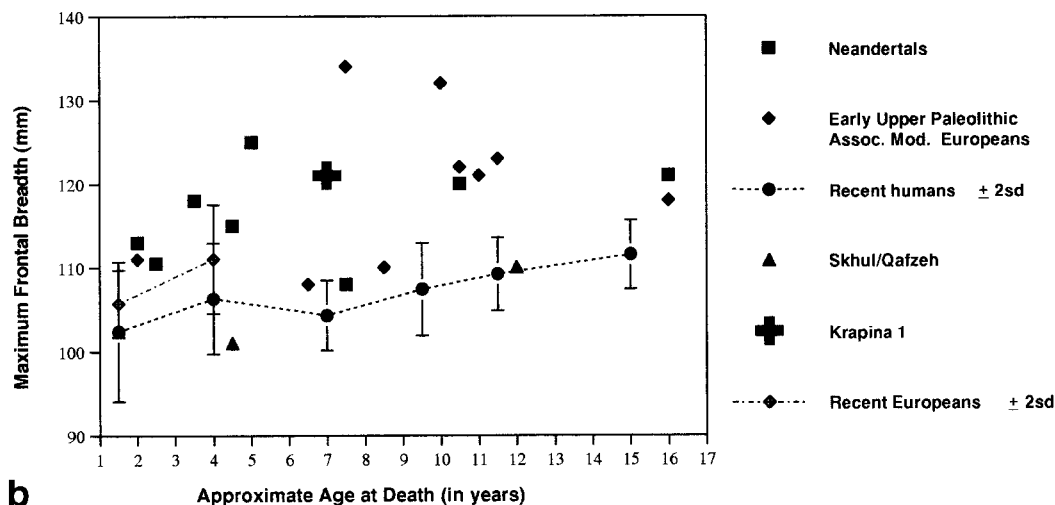


Fig. 5. Comparison of frontal breadth in Krapina 1, Neandertals, early Upper Paleolithic associated children, Skhul/Qafzeh, and recent modern children. (a) Minimum frontal breadth; (b) maximum frontal breadth. (Recent European data from Madre-Dupoy, 1992.)

browridge element. The immature Frontal 3 specimen, now catalogued as Krapina 24 from level 4, was perhaps developmentally younger than Krapina 1 at the time of death as suggested by its considerably thinner frontal squama (Minugh-Purvis, 1988a). However, even this extremely young child possessed a more robust lateral browridge element than Krapina 1 (Table 2).

Behind the supraorbitals the frontal rises fairly steeply. Although a true supratotal sulcus does not exist, a slight, continuous depression is both visible and palpable extending from the midline laterally along the left browridge. A subtle *trigonum supraorbitale* is present, although poorly defined given the specimen's young developmental age. The comparably aged La Quina 18 juvenile

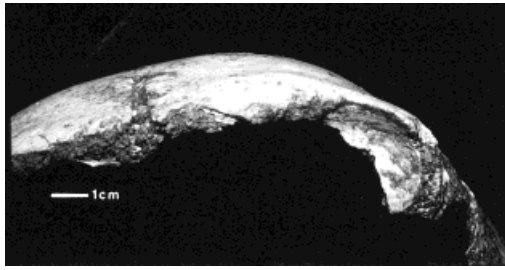


Fig. 6. The Krapina 1 left browridge (photo by F.H. Smith).

TABLE 2. Comparison of relative height of the medial and lateral supraorbital elements in young Neandertals and Krapina 1^{1,2}

	Height of lateral portion	Height of medial portion	Lateral/medial height index
Juvenile Neandertals			
Krapina 24 (Frontal 3)	7.6	11.9	64
Pech de l'Azé 1	[9.0]	13.3	[69]
Subalyuk 2	9.0	[12.0]	[75]
Devil's Tower 1	7.5	15.0	50
Engis 2	10.2	11.8	86
La Quina H-18	11.8	17.7	66.6
Carigüela 2	5.0	9.0	55
Teshik-Tash 1	9.0	15.2	59
Krapina 1	4.0	11.9	33.6

¹ All measurements in millimeters.

² Bracketed values represent estimated measurements or indices derived from estimated measurements.

Neandertal possesses a similar development of this feature. The anterior-posterior (AP) projection of the browridges from the Krapina 1 frontal squama (Fig. 1b and e) suggests that a supratoral sulcus would have developed eventually. Laterally, on the left, damage obscures the form of the browridge approaching the fronto-zygomatic suture. From what remains, it appears clear that this would have been thicker than the midvault browridge segment. In addition, it appears that the lateral orbital pillar was substantial in this child, as suggested by the 14.5 mm AP thickness of the left supraorbital at frontotemporale (identical to the same dimension in La Quina 18) and the considerable development of cancellous bone tissue where the left browridge is broken at its lateral extremity. The root of the left superiormost portion of the lateral orbital pillar is clearly sculpted by the anteriormost inferior temporal line. Unfortunately, its

thickness cannot be accurately estimated due to breakage. Above that, anteriorly, the superior temporal line is clearly marked. The marked development of both temporal lines, and the preserved portion of the anterior temporal fossa, indicates a strongly developed anterior temporalis muscle in this young child.

The small preserved section of left orbital plate, which extends 23.9 mm posteriorly, suggests a concave but shallow orbital roof, similar in form to those seen in the adult Krapina 3 (Krapina Skull C) and Krapina 6 (E Skull) crania. Apparently, the orbital cavity did not extend above the superior orbital margin in contrast to modern humans. Interestingly, the Gibraltar 2 Neandertal child exhibits a fairly deep concavity of the anterolateral orbital roof, more similar to that seen in living children of all developmental ages whereas the 7–7.5 year old La Quina 18 western European Neandertal more closely resembles Krapina 1 in possessing a lateral orbital roof which lies at the level of the superior orbital rim.

Frontal thickness, as already mentioned in the section on ageing, is consistent with the expected robusticity in a Neandertal juvenile of approximately 7 years at the time of death. Frontal thickness varies from 5.5–6 mm at bregma to between 5.0 and 2.8 mm further laterally along the coronal suture, thinning to 2.0 mm approaching pterion. At the frontal tuberosities, thickness is 4.0 mm on the left and 3.8 mm on the right. Compared with the Skhul 1 child, and the few available early Upper Paleolithic associated juveniles of mid-childhood age in which thickness at the frontal tuber ranges from 2.0–2.5 mm, the Krapina 1 frontal bone is rather thick.

To summarize, in all aspects of frontal morphology except a few characteristics of the browridge, Krapina 1 fits well within the range of metric and qualitative variation known for Neandertals. However, its browridge morphology lies at the extreme end of the range observable in other Krapina specimens and juvenile Neandertals of comparable developmental age and overlaps with the range of morphological variation for this structure exhibited by early modern Upper Paleolithic associated Europeans.

TABLE 3. Parietal dimensions for Krapina 1¹⁻³

Approx. age at death (years)	Krapina 1 6.0–8.0	Engis 2 4.0–5.0	La Quina 18 7.0–8.0	Teshik- Tash 1 10.0–11.0	Devil's Tower 4.0–5.0	Recent modern children ⁴ 6.0–7.9
Dimensions ⁵						
M30.2 Bregma- pterion chord	[90]	89.0	89.0	94.0	90.4	89.0 ± 4.19 (N = 19)
M27.2 Bregma- pterion arc	[110]	106.0	110.0	111.0	110.9	106.3 ± 5.32 (N = 20)
M27 Bregma-lambda chord	104.5	101.0	96.5	102.0	102.0	109.2 ± 6.05 (N = 22)
M30 Bregma-lambda arc	112.5	112.0	106.0	110.0	110.0	122.6 ± 7.19 (N = 22)
M30.3 Lambda-aste- rion chord	92.5	88.0	86.7	96.0	85.0	85.0 ± 4.71 (N = 21)
M27.3 Lambda-aste- rion arc	108.0	101.0	100.0	109.0	101.0	95.8 ± 5.3 (N = 21)
Indices ⁵						
M30.2/27.2 Index of coronal curvature	[81.8]	84.0	81.0	84.6	81.5	83.9 ± 1.95 (N = 19)
M27/30 Index of sag- ittal parietal curva- ture	92.9	90.1	92.7	92.7	92.7	89.0 ± 2.15 (N = 22)
M30.3/27.3 Index of lambdoid curvature	85.6	87.1	86.7	82.0	84.1	88.6 ± 1.95 (N = 21)

¹ All dimensions in millimeters.² Metric data after Minugh-Purvis (in preparation).³ Bracketed values represent estimated measurements or indices derived from estimated measurements.⁴ Metrics recorded as the mean ± 2 SD of a combined sample of mid-childhood age at death. After Minugh-Purvis (in preparation).⁵ Where applicable, metric dimensions and indices have also been identified by Martin (1928) reference numbers.

Parietals

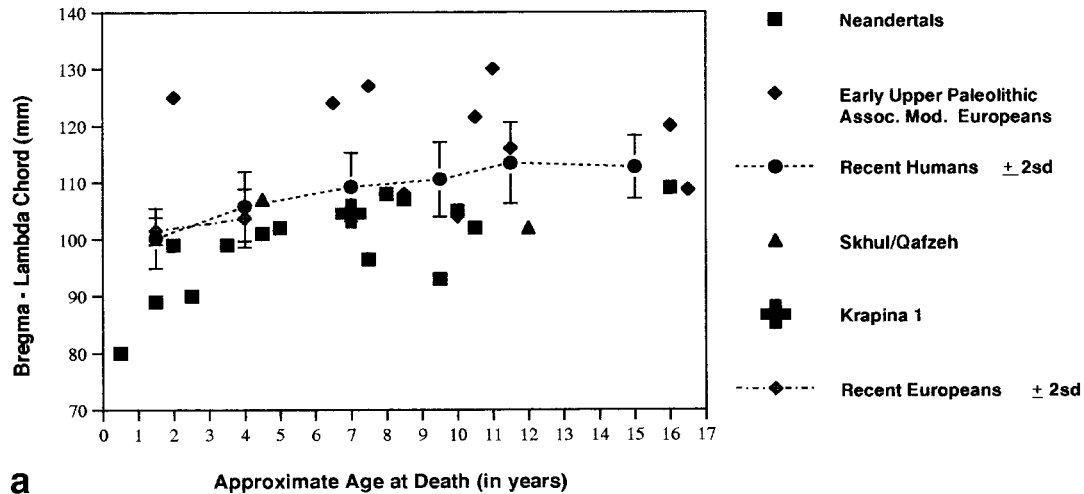
The well-preserved Krapina 1 parietals are slightly depressed or flattened posterior to the coronal suture at bregma (Fig. 1c and e), a common finding in crania of modern children (Hrdlička, 1930) and also present in such Upper Pleistocene specimens as the Skhul 1 (McCown and Keith, 1939) and Subalyuk 2 (Pap et al., 1996) juveniles. Metric comparisons of the parietal reveal that anteriorly the parietal coronal chord measures [90 mm] and the arc [110 mm], for a coronal index of curvature of [81.8] (see Table 3). The Krapina 1 coronal chord and arc fall entirely within the ranges for modern and all late Pleistocene European children of comparable developmental age. The same is true of coronal curvature.

In sagittal length, the Krapina 1 left parietal measures [104.5 mm] (chord) and [112.5 mm] (arc), although the occurrence of a (missing) ossicle at lambda makes it necessary to estimate these lengths, however with considerable confidence. These values yield an index of sagittal parietal curvature of 92.9 for the child. For midvault length,

Krapina 1 clearly falls with Neandertal children possessing, in absolute terms, a considerably shorter sagittal parietal chord than the modern samples examined (Fig. 7a). For bregma-lambda arc length (Fig. 7b), Krapina 1 falls below the modern range and well within the range of variation displayed by immature European Neandertals. We emphasize that this short midvault segment represents the *primitive* condition of this feature and is not, therefore, a distinguishing feature of Neandertals (Minugh-Purvis, 1998; in preparation). It is obvious here, however, that Krapina 1 falls, along with the archaic specimens, well below the ranges for parietal sagittal length seen in the recent modern children from the various samples examined. It also falls well below the range for the early modern Upper Paleolithic associated Europeans and the Levantine early modern Skhul 1 child, although Qafzeh 11 falls with the more archaic specimens for both bregma-lambda chord and arc length (Minugh-Purvis, 1998).

Posteriorly, the lambdoid margin of the Krapina 1 left parietal measures [92.5 mm]

Comparison of Parietal Sagittal Chord Length in Krapina 1



Comparison of Parietal Sagittal Arc Length in Krapina 1

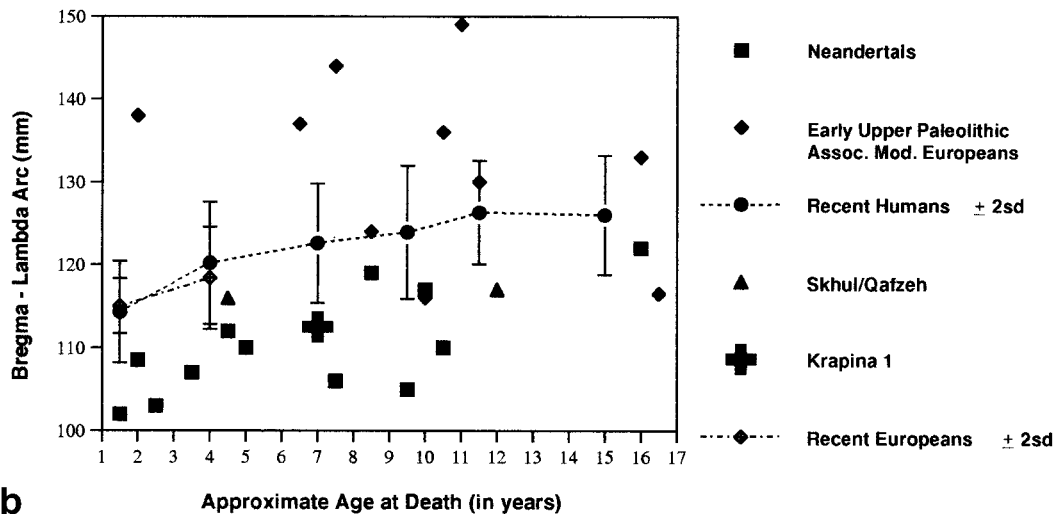
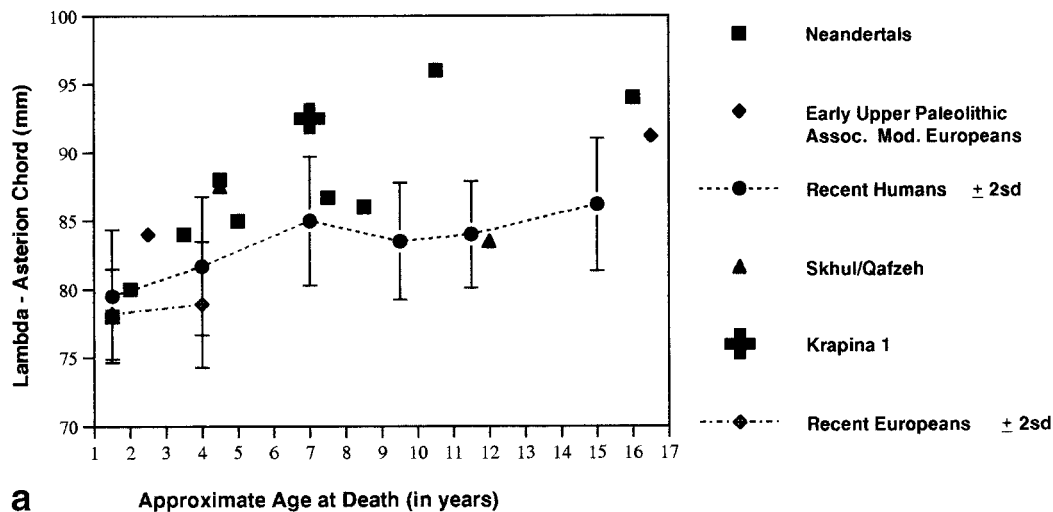


Fig. 7. Comparison of parietal sagittal length in Krapina 1, Neandertals, early Upper Paleolithic associated children, Skhul/Qafzeh, and recent modern children. (a) Chord length. (b) Arc length. (Recent European data from Madre-Dupoy, 1992.)

(chord) and [108 mm] (arc) with both values necessarily estimated, albeit with confidence, due to the missing lambdoid ossicle. The index of lambdoid curvature in Krapina 1 is approximately 85.6 mm. Metric comparisons of the posterior parietal margin, (Fig.

8a), indicate that Krapina 1 possessed a relatively long lambdoid border, falling at the upper end of the late Pleistocene European range. Comparisons of lambdoid arc length (Fig. 8b) show a similar pattern. Very few early Upper Paleolithic associated mod-

Comparison of Lambdoid Chord Length in Krapina 1



Comparison of Lambdoid Arc Length in Krapina 1

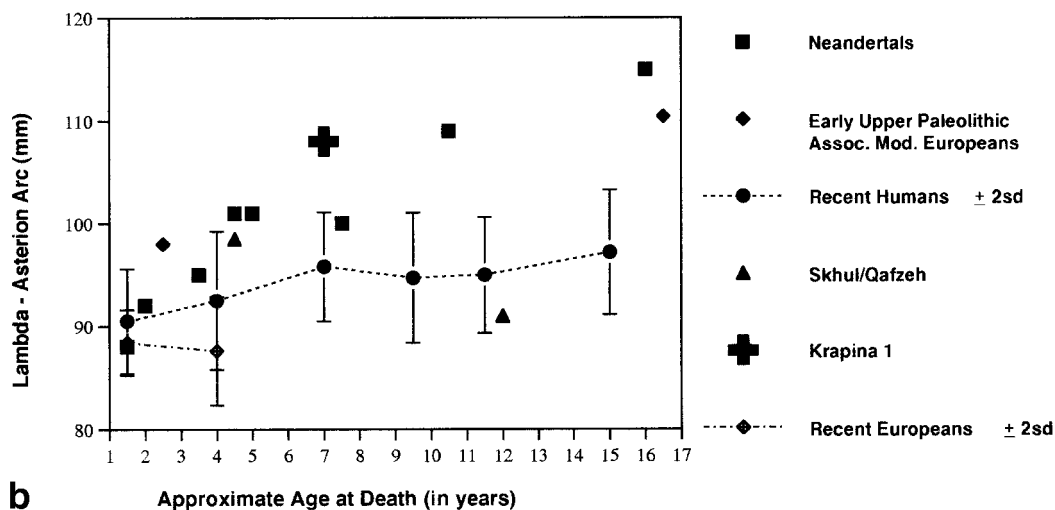


Fig. 8. Comparison of lambdoid length in Krapina 1, Neandertals, early Upper Paleolithic associated children, Skhul/Qafzeh, and recent modern children. (a) Chord length. (b) Arc length. (Recent European data from Madre-Dupoy, 1992.)

ern European children are available for comparisons with these dimensions, and Krapina 1 is metrically indistinguishable from these as well as Neandertals of comparable developmental age.

Also posteriorly, the Krapina 1 parietals lose their convexity and are markedly flattened in the vicinity of lambda (see Fig. 1a,

d, and e). This flattening is evident in a reduction of curvature in the coronal plane of the medial left and right posterior parietals as they approach the sagittal suture and in the AP curvature of the medial portion of both bones as they approach lambda. In addition, from a posterior view, the cranium possesses somewhat of a pentagonal poste-

rior profile, although not of the usual form typical in modern children such as the Skhul 1 Upper Pleistocene Levantine child (Minugh-Purvis, 1998). Whereas in Krapina 1 the parietal bosses are near the top of the vault, so that the midvault segment is extremely flattened above that level, more modern specimens, such as the Skhul 1 child, possess a vault that continues to rise well above the level of the parietal eminences. The other reasonably complete Krapina crania, the Krapina 3 and 6 adults, also possess somewhat of a pentagonal posterior form. A semblance of this is also reported by Thompson and Bilsborough for the French adolescent Neandertal from Le Moustier (Thompson and Bilsborough, 1997), and the Spy 1 adult Neandertal from Belgium clearly exhibits a more pentagonal as opposed to oval posterior vault profile (Wolpoff, 1995). This shape should, therefore, be considered as one variant within the Neandertal range of posterior cranial vault form—different from the more oval posterior cranial outline common in Neandertals from Western Europe. No posterior parietal foramina are visible on the external surface of the Krapina 1 parietals nor is Krapina 1 unique in this regard. These foramina are also lacking in the Krapina 2 (formerly Skull B) juvenile.

On the parietals both the superior and inferior temporal lines are apparent where not obscured by shellac. The inferior temporal line is fairly easily discerned on the bone anteriorly. Its closest approximation to the squamosal suture, just posterior to the coronal suture, is 15 mm. The left and the right temporal lines most closely approach each other at the coronal suture, where they are separated by approximately 126 mm. In the region of middle temporalis attachment, the inferior temporal line is barely discernible, although this is likely due to effects of the shellac covering the bone. However, a well-defined elevation occurs at the posterior margin of the *m.temporalis* attachment suggesting a strongly developed posterior component of the muscle, a common finding in Neandertals after the onset of secondary dental eruption (Minugh-Purvis and Lewandowski, 1992).

Parietal thickness varies along the left lambdoid suture from 4.7 mm at lambda to 3.6 mm at asterion. Vault thickness at the left parietal boss is 4.0 mm. Thickness along the sagittal suture varies from between 5.5 to 5.0 mm, and thickness along the coronal suture varies from 4.0 to 6.0 mm, averaging 5.0 mm in thickness at bregma. These values are entirely consistent with those for other Neandertal juveniles of comparable developmental age. Compared with Skhul 1, the few early Upper Paleolithic associated juveniles of mid-childhood age, and recent modern children, the Krapina 1 parietal bone is at the thick end of the range of variation.

Temporal

The left temporal of Krapina 1 is virtually complete except for the antero-superior squamous, which is missing approximately 12.9 mm of bone posterior to the spheno-squamosal suture. However, the sutural margin of the inferior squamous, where it articulates with the greater wing of the sphenoid, is beautifully preserved. The temporal squamous measures [61 mm] from the spheno-squamosal suture to the temporal incisure and [77 mm] in total length (see Table 4). This length places the specimen high, but within, the range of variation for Neandertals and possibly also early Upper Paleolithic associated modern Europeans (see Fig. 9a and b). The squamous rises [37 mm] above the level of porion, again at the high end of the Neandertal and recent European range and between the two data points available for early Upper Paleolithic associated modern Europeans (see Fig. 9c). The temporal height/squamous length to incisure index is [60.6], within the range for Neandertal children of early to late childhood age. Compared with other groups, the maximum squamous length to squamous height index of [48] in Krapina 1 places the specimen within the Neandertal range and, as is typical of Neandertals, lower than recent moderns. The squamous is flat vertically, with little apparent curvature from superior to inferior, although AP curvature is present. McCown and Keith (1939) note that in modern human skulls the mastoid and squamous parts of the upper temporal border are sharply delimited, the squamous arching well above the Frankfort plane. This

TABLE 4. Temporal dimensions for Krapina 1¹⁻³

Approx. age at death (years):	Krapina 1 6.0–8.0	Engis 2 4.0–5.0	Devil's tower 4.0–5.0	La Quina 18 7.8–8.0	Teshik-Tash 1 10.0–11.0	Recent modern children ⁴ 6.0–7.9
Dimensions						
Maximum height of squamous above porion	[37]	31.3	—	33.0	32.6	40.8 ± 4.23 (N = 22)
Squamous length (to incisure)	[61]	54.2	48.8	51.0	58.2	54.8 ± 2.12 (N = 7)
Maximum A-P length	[77]	73.0	[74]	[76]	74.0	77.3 ± 3.2 (N = 15)
Mastoid height (from porion)	17.4	13.7	13.4	13.3	12.4	16.2 ± 3.12 (N = 8)
Mastoid breadth	18.4	15.6	16.1	16.6	17.6	16.5 ± 3.19 (N = 8)
Glenoid fossa, M-L breadth	15.0	15.9	12.0	15.3	18.9	15.0 ± 1.15 (N = 8)
Glenoid fossa, maximum A-P length	9.0	9.8	7.8	10.0	8.6	10.3 ± 1.8 (N = 8)
Indices						
Squamous height/maximum length	[48]	42.8	—	43.4	44.0	55.3 ± 3.7 (N = 15)
Squamous height/length to incisure index	[60.6]	72.6	—	64.7	50.7	65.4 ± 3.2 (N = 7)

¹ All measurements in millimeters.² Metric data after Minugh-Purvis (in preparation).³ Bracketed values represent estimated measurements or indices derived from estimated measurements.⁴ Metrics recorded as the mean ± 2 SD of a combination of several samples of recent modern children who died during mid-childhood. From Minugh-Purvis (in preparation).

appears to be true of Krapina 1 as well as specimens such as the Gibraltar 2 Neanderthal child, which has a fairly marked notch separating the squamous and petromastoid portions of that bone (Minugh-Purvis, personal observations).

Laterally, the external surface of the temporal bone presents considerable pitting, which is discussed in the section on pathology. Part of the origin of posterior temporalis is clearly visible as an elevated surface with its margin extending above the external auditory meatus as a mildly developed bony buttress. This buttress sweeps posteriorly as the incipient supramastoid crest and then superiorly some 31 mm from its origin to become continuous with the temporal line. The entire temporal fossa is clearly outlined as a slightly raised area over much of the posteroinferior portion of the squamous temporal, except where a weak supramastoid crest outlines the limits of attachment for the most inferior fibers of the posterior temporalis muscle. A few tiny foramina open onto the smooth supramastoid surface of the squamous temporal, and a mastoid foramen for a mastoid emissary vein appears to drain endocranially into a large foramen situated at the root of the unusually large superior

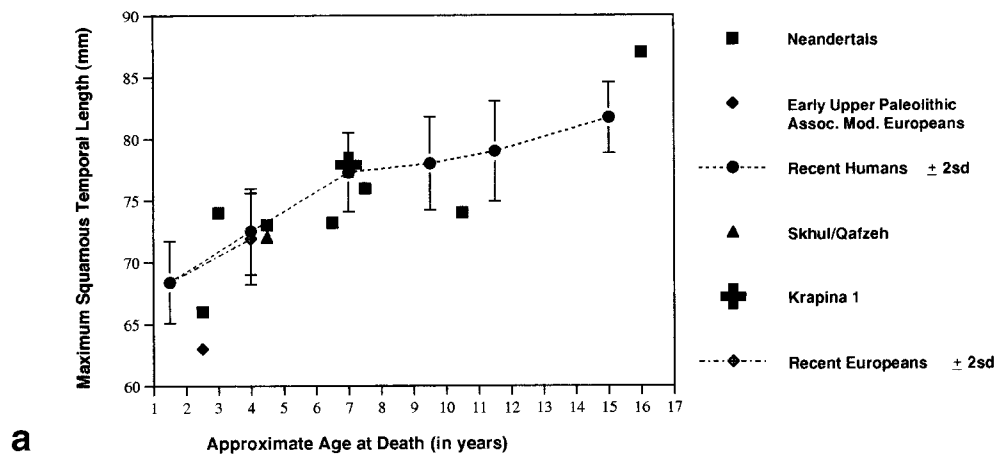
petrosal sinus (see Fig. 1e). Externally, a large foramen opens onto the inferior temporal squamous 4 mm posterosuperior to the suprameatal triangle, and directly communicates with a persistent petrosquamous sinus endocranially.

The external auditory meatus is a slightly oval aperture, some 8.95 mm in maximum diameter, with a long axis inclined slightly anteriorly from the vertical as in modern humans. A well-marked suprameatal triangle, consisting of a depression approximately 5 mm superior to the upper margin of the external auditory meatus, is present.

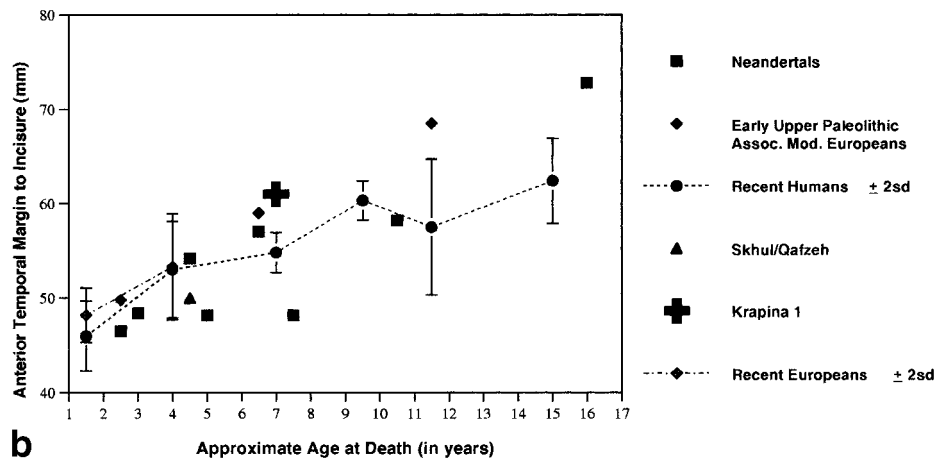
Krapina 1 possesses a fairly well developed mastoid process (Figs. 1c and 1d and 10). At its root, the mastoid measures 18.4 mm in breadth, while its width at the level of porion is 26.8 mm. Height of the free mastoid process measures 12.65 mm, while the apex is some 17.4 mm below the level of porion and projects 4.2 mm below the floor of the digastric groove. At these dimensions,

Fig. 9. Comparison of the squamous temporal in Krapina 1, Neandertals, early Upper Paleolithic associated children, Skhul/Qafzeh, and recent modern children. (a) Maximum squamous length. (b) Temporal squama length. (c) Squamous temporal height. (Recent European data from Madre-Dupoy, 1992.)

Comparisons of Maximum Squamous Temporal Length in Krapina 1



Comparisons of Temporal Squama Length in Krapina 1



Comparisons of Squamous Temporal Height in Krapina 1

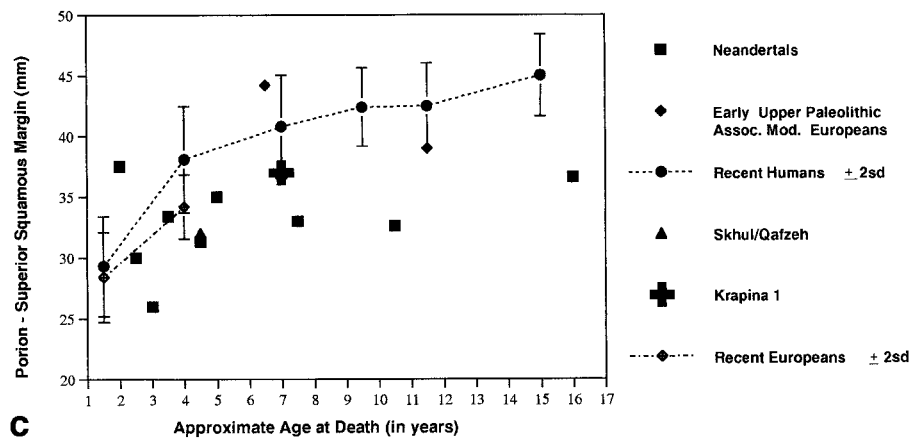


Fig. 9.

the Krapina 1 mastoid is larger and more distinctly protrusive from the squama than typically seen in Neandertal children in Western Europe or the Levant (Minugh-Purvis, personal observations). However, a comprehensive survey of mastoids in the Krapina sample reveals considerable variation in degree of mastoid development within that group, with many specimens exhibiting well developed mastoids (Smith, 1976). Thus the expression of this feature in Krapina 1 is not outside of the Neandertal range of variation. In addition, the mastoid tip is directed slightly posteriorly, an orientation seen in other Krapina fossils.

Other aspects of the Krapina 1 mastoid region conform closely to typical Neandertal morphology (Fig. 1d). The inferiormost posterior temporal, comprising the most anterior portion of the cerebellar fossa, drops 9.3 mm below the mastoid tip so that medial to the digastric groove the Krapina 1 temporal continues to curve inferiorly into a well-developed juxtamastoid eminence, a feature seen elsewhere in the Krapina collection. The area of the juxtamastoid eminence is slightly eroded and some surface bone is missing, but this feature is clearly present, nevertheless. A juxtamastoid eminence is lacking in modern children, both Pleistocene and recent, whose temporal bones level off medial to the digastric groove. Further laterally on the Krapina 1 posterior temporal, the well-marked origins of *m. sternocleidomastoid* and *m. splenius capitis* form the superior nuchal line.

The Krapina 1 glenoid fossa measures 15.0 mm in maximum transverse breadth, and between 5.9 and 9.0 mm anteroposteriorly. It is fairly well-excavated (Figs. 1c and e and 10a and b) with a definite articular eminence anteriorly, quite in contrast to the shallow, flattened articular surface lacking an articular eminence so often found in western European Neandertals. Among the Krapina temporals, a considerable range of variation in glenoid depth is found, with specimens such as Krapina 3, 4, and Krapina 38.4 (Temporal 11) exhibiting deeply concave glenoids; Krapina 39.3 (Temporal 4) exhibiting a moderate amount of concavity; and Krapina 39.2 (Temporal 3)—a child of similar developmental age at death as

Krapina 1—exhibiting the flattened morphology more typical of western European specimens. Thus, although possessing a fairly deep glenoid, Krapina 1 fits into the range of glenoid morphology seen at this site. There is no evidence of the plesiomorphic participation by the sphenoid to the medial glenoid wall such as is found in modern humans nor is this seen in other Krapina specimens (see also Smith, 1976). Laterally, a slight post-glenoid tubercle is present, of a similar degree of development to those found in comparably aged recent modern children. A strongly developed, rugose lateral edge is present on the articular tubercle of the temporal for attachment of the tempromandibular ligament.

The glenoid fossa is oriented nearly horizontally, although it appears that the actual articular surface was not quite yet in the horizontal plane at the time of death. The articular eminence lies anterior to the glenoid fossa and is continuous laterally with the zygomatic root. At its most anterior margin, the articular eminence fades into the basal squamous, while medially it descends to form a strongly beaked entoglenoid process. The tympanic ring had totally fused. The tympanic portion of the glenoid fossa is smoothly and continuously convex from anterior to posterior, not “concave in all directions” as Breathnach (1965) describes for moderns. In this regard, Krapina 1 is similar to Krapina 39.3 (Temporal 4). Krapina 3 (Skull C) is flatter, and Krapina 39.1 (Temporal 1) is flatter still.

The well-marked origin of the posterior digastric muscle is represented by a single digastric groove (Fig. 10b), with a maximum width of 4.2 mm, a length of 20.5 mm, and a depth of 3.75 mm. Most of the Krapina temporals possess a single digastric groove, the exceptions being Krapina 17 and Krapina 39.3 (Temporal 4), both of which exhibit an additional incisure medial to a larger digastric groove. In Krapina 1, bony breakage obscures much of the surface morphology medial to the digastric groove, although a shallow, tiny groove for the occipital artery is visible here. The stylomastoid foramen, located totally on the inferior surface, is separated from the digastric groove by a bony bridge, 7.8 mm wide.

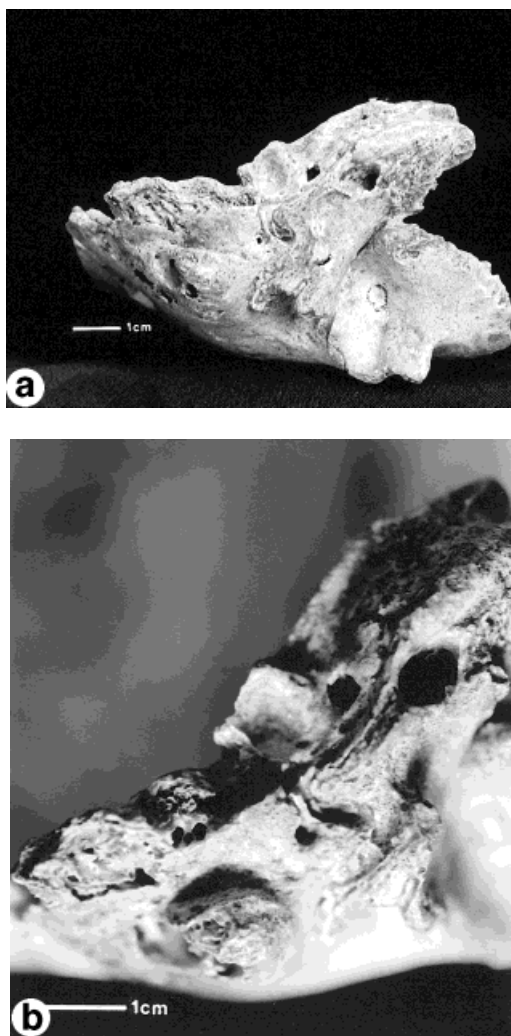


Fig. 10. The Krapina 1 temporal. (a) Basal view showing glenoid fossa. (Photograph by Dražen Pomykalo.) (b) Basal aspect showing mastoid projection and tympanic plate. (Photograph by Doug Purvis.)

Nearly the entire length of the petrous has been preserved. The stylomastoid foramen is situated well under the skull in the horizontal plane. Anterior to the stylomastoid foramen is the broken base of the styloid process. The styloid base had commenced ossification and the root is visible. It is surrounded by the hollow vaginal process, some 7.05 mm in diameter, which anchored it in life. From the styloid root, the posterior tympanic plate continues medially some 10 mm until interrupted by the margin of the

large, basal opening of the carotid canal. Anteriorly, a small persistent opening, or foramen of Huschke, perforates the tympanic plate. The foramen's original size cannot be determined with certainty as it appears to have been slightly enlarged by artificial chipping around its margins. A tiny patent channel incises the most inferior portion of the anterior tympanic crest, dividing it into two lips. This connects the foramen of Huschke with the inferior rim of the external auditory meatus.

The form of the tympanic plate in this specimen is quite interesting. Its inferior surface is divided into anterior and posterior areas by a two part tympanic crest. This produces a bipartite tympanic plate (Fig. 10b) reminiscent, but not identical to, those typical of European Neandertals (McCown and Keith, 1939; Guth, 1978). Immediately anterior to the vaginal process, the anterior lamina of the tympanic plate sweeps inferiorly to a strong crest, which terminates in a broken process some 3.5 mm thick. Protruding medial to this is the posterior portion of the tympanic crest which extends to the carotid canal margin. This division of the tympanic plate into two surfaces appears to have resulted from a different pattern of union in Neandertals among the elements making up the tympanic plate. In modern humans, this union occurs along a line of fusion following the long axis of the petrous from its tip to the mastoid process. In Krapina 1, however, this fusion was not entirely linear with the result that the lateral portion of the tympanic crest lies anterior to the location of that ridge in modern children, positioning it at the location of the anterior tympanic ridge in Neandertals. Thus, Krapina 1 exhibits a variant of the divided tympanic plate of Neandertals. Because the distinctive morphology of the Neandertal tympanic plate appears to be the result of a unique developmental pattern, tympanic plate development should perhaps not be considered appropriate for estimating the age at death in Neandertal specimens until such time as a correlation with Neandertal dental age has been established.

Posterior to the posterior lamina of the tympanic plate is the extremely small fossa for the jugular bulb, only 6.5–7.3 mm in

diameter. The depression for the petrous ganglion of cranial nerve IX is well-marked as a deep, triangular fossa medial to the jugular fossa. Lateral to the jugular fossa, the small jugular notch, 4.2 mm in diameter, is present. There is no groove for the sigmoid sinus.

Despite some local bony erosion, the mastoid canaliculus for the auricular branch of cranial nerve X is visible piercing the anterior rim of the jugular fossa. Between the mastoid process and tympanic plate is a tiny foramen for the posterior auricular branch of cranial nerve X. The foramen for the tympanic branch of cranial nerve IX is preserved just posterolateral to the carotid canal as in modern humans. The uppermost recess of the fossa of Rosenmüller, marking the origin of the *m. levator veli palatini* and the temporal anchorage of the cartilaginous auditory tube, is present between the tegmentum and petrous. Further medially on the inferior aspect of the petrous is the well-preserved sizeable entrance to the carotid canal, which measures 5.4 and 7.4 mm in minimum and maximum diameter, respectively. The medial course of the carotid canal is exposed by breakage to the anterior petrous. Fusion between the squamous and petro-mastoid portions is complete ectocranially and endocranially. The *tegem tympani* is apparent in the inner part of the squamotympanic fissure.

Endocranium

Although the endocranial surface bears numerous well-defined impressions of the cerebral cortex, its most prominent features are vascular grooves. Pacchonian pits are barely detectable; not surprisingly, as these features become increasingly exaggerated with age (Warwick and Williams, 1973).

Meningeal vascular patterning. The grooves for the middle meningeal arteries and their accompanying veins are strongly etched into the endocranial surfaces of the vault bilaterally, although they are best visualized on the more intact left side. Numerous emissary foramina are present around the terminations of the meningeal grooves. Branches of the anterior division of

the middle meningeal vessels are more strongly marked on the left than on the right frontal moiety. These run anteriorly from the region of pterion.

On the left parietal, three grooves for the middle meningeal vessels are very well defined, with the anterior branch being by far the largest (see Fig. 11a and b). The course of the vessels is not unexpected; some run superiorly and others coursing obliquely toward the occipital region. The anterior branches of the middle meningeal appear to run parallel to the entire length of the once underlying central sulcus of the cerebral cortex. Superiorly, overlapping with the terminal course of the anterior branch of the middle meningeal vessels is a large anterior vein that merges into the sinus of Breschet. The groove for this vessel has a maximum width of 5.0 mm on the left and 4.3 mm on the right. In modern human adults, one branch of the frontal division of the middle meningeal vessels lies approximately 1.5 cm behind the coronal suture, at the approximate position of the precentral sulcus (Williams et al., 1989, 740). In Krapina 1 these grooves are found at an average distance of 8.3 mm posterior to the coronal suture approaching bregma. By comparison, in the Krapina E adult, the groove for these vessels lies approximately 12 mm posterior to coronal suture, whereas in Krapina 17 they lie some 10 mm posterior to the coronal suture at the terminal extent of their course.

The middle division of the middle meningeal does not branch off the anterior division in the parietal region. Rather it is well-defined and separate for its entire course on the left parietal. Grooves for the posterior branch are present on the temporal endocranium where they cut, horizontally, across the length of the squamous temporal. This pattern of ramification closely resembles the most common Pleistocene pattern described by Saban (1980, 1981, 1986) in which the vessels apparently ramified close to the foramen spinosum.

In Krapina 1, the posterior division of the middle meningeal vein consisted of two small tributaries which united near parietal asterion, crossed the temporal incisure, then

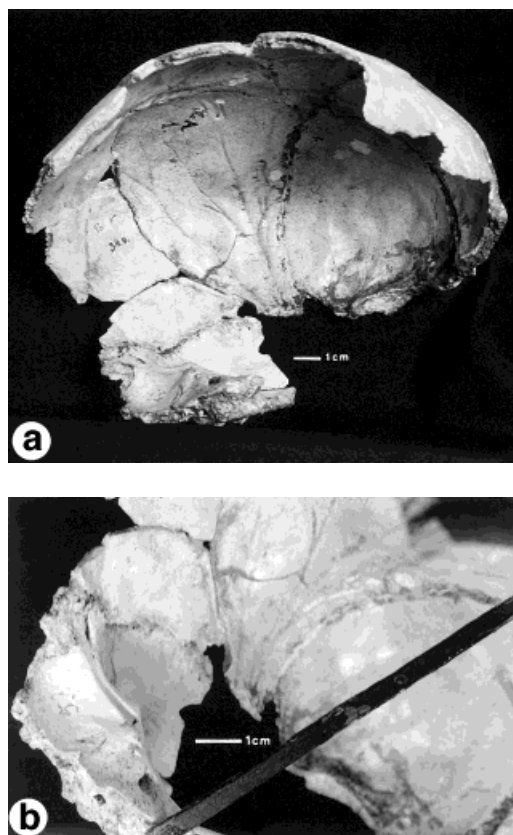


Fig. 11. Vascular patterning on the Krapina 1 endocranium. (a) Grooves for the middle meningeal vessels. (Photograph by Dražen Pomykal.) (b) Superior petrosal sinus. (Photograph by Doug Purvis.)

descended anteroinferiorly to join the petrosquamous sinus. Another tributary of the posterior division was situated slightly more superiorly on the inferior parietal endocranium, crossed the squamosal suture 10.1 mm superior to the temporal incisure, and ran for some 21.16 mm across the squamous temporal endocranium before descending abruptly anteroinferiorly to join the groove for the common middle meningeal trunk just above the latter's juncture with the petrosquamous sinus.

Saban (1980) has noted that Neandertals exhibit a sparser anastamotic pattern between the middle meningeal vessels than do modern humans. Although Krapina 1 exhibits a rich anastamotic network in the *parietal* region, more consistent with Saban's (1981) 8-year-old modern human pattern

than with Neandertals, its blood supply to the *frontal* endocranium originates from the anterior division of the middle meningeal and is thus more consistent with the Neandertal pattern. In addition, the presence of Breschet's sinus, recognized as a common feature of the Neandertal meningeal venous system (Heim, 1974), and the persistence of the petrosquamous sinus identified as a common peculiarity of the Neandertal endocranial venous drainage (Saban, 1980), are consistent with a Neandertal morphology.

Dural venous sinus drainage. Endocranially, several impressions for dural venous sinuses are evident. On the frontal endocranium, a matrix-filled foramen present anteriorly at the base of the midline may represent the *foramen caecum*. The margins of each frontal moiety bordering the metopic suture are slightly elevated for attachment of the anteriormost *falx cerebri*. These run approximately 40 mm from the supranasal region to a position corresponding, externally, to the position of metopion. A shallow, narrow groove, rising superiorly from the frontal crest, appears to have accommodated the anterior portion of the superior sagittal sinus. This disappears at the approximate location of metopion, then becomes visible again 11 mm anterior and to the right of bregma, becoming increasingly well excavated as it passes onto the parietals. Typically, this groove is to the right of the sagittal suture in modern humans as well (Breathnach, 1965).

In the region of bregma and along the posterior half of the right parietal, the groove for the superior sagittal sinus is pierced and surrounded by numerous, tiny emissary foramina for diploic veins. In addition, numerous small foramina pierce the inner bony table on either side of the ridges defining the groove for the superior sagittal sinus. These are found along the entire length of the sinus impression along the superior vault but are notably more numerous in the posterior two-thirds of the parietals. The groove for the superior sagittal sinus is most strongly marked from approximately 45 mm posterior to bregma to the vicinity of lambda. Here the margins of the groove are well-

marked for attachment of the *falx cerebri*. Its width, measured between the bony ridges that define the margins of the dural attachments enclosing the sinus, varies from 9.0 to 9.5 mm throughout most of its length. As previously described, strong impressions for the frontal transverse venous sinus, or Brechet's sinus, appear on the left and right parietals just posterior to the coronal suture.

No groove for the transverse sinus is evident on the Krapina 1 left parietal, although a portion of this bone's posterior-inferior corner is missing. On the Krapina 3 adult (Krapina C Skull) the groove for the transverse sinus forms a very slight concavity along the sutural border of the inferior parietal before passing to the temporal. Thus, the absence of this groove in Krapina 1 could be due to a similar course as in Krapina 3.

The pattern of dural sinuses preserved on the endocranial aspect of the left temporal is most unusual (Fig. 11b) (Minugh-Purvis et al., 1995 and in preparation). One striking feature of this area is the large groove for the superior petrosal sinus, which runs anteromedially 62.4 mm from the region of endoasterion, where it is continuous with the transverse sinus to the petrous tip. A large oval foramen (6.7×1.7 mm) opens into the groove for the superior petrosal sinus laterally. The groove for the superior petrosal sinus deeply incis the superior petrosal margin, including the posterior aspect of the arcuate eminence. At the medial end of the petrous portion it bifurcates, forming one channel which passes posteroinferiorly, while the direct continuation of the sinus maintains a medial course. Ectocranially, this site is marked by an emissary foramen too small to demonstrate confluence/communication with the superior petrosal sinus. Finally, on the posterior petrosal face, another foramen opens into this channel at the subarcuate fossa, and the groove for the superior sagittal sinus is wider medial to this junction.

Slightly anterior to the large foramen, opening at the root of the superior petrosal sinus is another, slightly smaller foramen (approximately 3.7×2.15 mm). From this foramen, a venous channel curves first superolaterally, then anteriorly for a very short

(2–3 mm) course, then hooks strongly medially before straightening somewhat. It then continues medially in a deep groove just posterior to the line of petrotympanic fusion along the anterosuperior surface of the petrous temporal. This strong curvilinear impression, representing a persistent petrosquamous sinus, runs from the junction of the petrosal and squamous portions anteromedially on the anterior petrous until it is truncated by damage to the bone. It is of approximately the same depth and breadth as the groove for the superior petrosal sinus. No drainage foramina are seen communicating in the usual position between this channel and the articular fossa externally. However, a large foramen opens through the lower temporal squama that appears to have directly communicated with this persistent embryonic remnant of the child's intracranial venous drainage.

None of the other Krapina temporals present a superior petrosal sinus groove of the size seen in Krapina 1. Even more remarkable is the complete lack of any groove for a left sigmoid sinus, although that feature is quite prominent on all of the other Krapina temporals preserving this region, including immature specimens such as 39.3 (Temporal #4). This apparent absence of the sigmoid sinus is consistent with the previously noted unusually small jugular fossa, and the enlarged superior petrosal sinus that clearly functioned to compensate for the lack of the sigmoid sinus in this child. This, and other variants of venous drainage among the Krapina people are discussed in more detail elsewhere (Minugh-Purvis, et al. 1995, in preparation).

Endocranial aspect of the petrous temporal.

The posterior aspect of the petrous portion (Fig. 11b) appears to have been oriented at approximately 45° to the horizontal as in Neandertals, rather than being oriented in a nearly vertical plane as in modern humans. As a result, the large internal acoustic meatus, measuring 5.2–4.6 mm in diameter, opens posterosuperiorly, whereas in modern humans it is confined entirely to the posterior aspect of the petrous. In both the very young infant Krapina 41 temporal, and in the adult Krapina 3, the

internal acoustic meatus also faces more superiorly than in modern humans.

The vestibular aqueduct is 11.7 mm lateral to the internal acoustic meatus. The aqueduct is beautifully preserved, measuring 5.5 mm at its base. A prominent arcuate eminence, suggesting a strongly vertical orientation for the superior semicircular canal is present 38.4 mm posterolateral to the petrous tip. A prominent arcuate eminence is also found in Krapina 38.21 (Temporal 41) and Krapina 17. However, in Krapina 3 (Skull C), this feature is noticeably smaller, resulting in a flatter superior petrosal surface. The Krapina 1 subarcuate fossa presents as a deep notch (approximately 7.5 mm long) which impinges on the posterior lip of the groove for the superior petrosal sinus. The margins of the subarcuate fossa appear folded suggesting perhaps a slight twisting of the dural attachment at that site. No cochlear aqueduct is visible, although it is possibly obscured by matrix. The most medial tip of the posterior petrous presents a depression for the inferior petrosal sinus and a well-defined notch for cranial nerve V. Continuing onto the anterior petrous, this groove for cranial nerve V merges into a slight concavity for the trigeminal ganglion, although only a small portion of this anterior fossa is preserved due to postmortem damage and loss of surface bone over most of the anterior petrous tip. Also anteriorly, the canaliculi and lateralmost sulci for the greater and lesser petrosal nerves are visible around the broken floor of the groove for the petrosquamous sinus, some 21 mm lateral to the petrous apex.

Total vault

Studied in *norma frontalis* (Fig. 1a), the Krapina 1 vault appears broad and low. The nearly complete left temporal of Krapina 1 shows a high, vertically oriented squama. This is more similar to the temporal morphology of modern and early Upper Paleolithic associated subadults than to young Neandertals, in whom the squamae are slightly curved due to the lower position of the greatest breadth of the skull.

The great breadth of the specimen, confirmed by metrics as pointed out earlier, is also evident from *norma verticalis* (Fig. 1b).

This view demonstrates that Krapina 1 possessed an elongated, broad cranium with its greatest breadth occurring near the middle rather than the posterior parietal. This view also gives the impression that, in addition to being broad, the cranium was very large overall. Unfortunately, its maximum length cannot be determined in the absence of the occipital bone. A small amount of postorbital constriction is present on the left side where the temporal line is intact at the posterior left lateral orbital pillar. This appears comparable to that seen in normal living children at the more constricted end of the modern range of variation.

Norma lateralis (Fig. 1c and e) also illustrates the low frontal profile of the Krapina 1 cranium, although the precise degree of vaulting cannot be determined as orientation in the Frankfurt plane is necessarily estimated due to the absence of the orbital floors. However, due to the preservation of the petrous temporal, it is possible to estimate the position of basion. This permits an estimated measurement of basion-bregma height in Krapina 1 at (120–125 mm), similar to the Neandertal children Engis 2 (115 mm), La Quina 18 (120 mm), and Teshik-Tash 1 (128 mm) but also similar to those of recent modern children of comparable developmental age (Minugh-Purvis, 1988a).

In *norma occipitalis* (Fig. 1d), the proximity of the parietal tubers to the superior surface of the vault is evident. As mentioned earlier, rather than presenting a pentagonal form equivalent to that described for early modern specimens, the posterior profile of the Krapina 1 cranium is entirely consistent with the morphology of this region in the other Krapina crania. Although Krapina 1 lacks the extreme, ovoid posterior profile typical of western European Neandertals, this morphology is rare at Krapina where it is known only from the Krapina 2 (Skull B) juvenile.

Although initial impressions suggest that Krapina 1 is rather gracile for its size, comparisons of muscle attachment areas to those of European Neandertal children reveal an entirely comparable degree of development for the temporal lines and the digastric groove. The mastoid process is fairly

rugose but is within the range of variation for other mastoids at Krapina.

PATHOLOGY

Krapina 1 shows evidence of pathological bone erosion centered in the left temporal region (see Fig. 10a and b). This may have resulted from otitis media and subsequent mastoiditis in that it strongly resembles the bony damage resulting from such infections as described by McKenzie and Brothwell (1967) and Rathburn and Mallin (1977).

The external aspect of the mastoid process presents numerous perforations of its compact bony shell, exposing the mastoid air cells. This bony erosion continues into the posterior-inferior temporal squamous (more precisely, in the area immediately superior to the mastoid root). Small surface lesions present on both the internal and external aspects of the temporal as follows. Externally, these are found superiorly on the middle and, to a lesser extent, the posterior temporal squamous. More anteriorly (where the only inferior portion of the squama has been preserved) they are seen on the inferior squamous as well, approaching to within 8.5 mm of the zygomatic root. The small articular eminence of the temporal reveals additional pathological pits. Outside of the mastoid region, pitting is most striking on the superior portion of the temporal squama, continuing onto the parietal. Similar lesions of the internal bone surface are also readily apparent. Some slight erosion is seen at the middle and base of the temporal squamous endocranium, with pitting strongly scarring the left parietal endocranium posterior and posterosuperior to the squamosal suture. This pitting extends to the right parietal as well. Interestingly, an isolated juvenile right temporal from the site, Krapina 38.4 (Temporal 11), which is metrically nearly identical to the Krapina 1 left temporal, also exhibits scattered, similar pitting.

To summarize, external pitting densely scars the antero-superior left squamous temporal and overlaps onto the parietal of Krapina 1. Sporadic pitting is also notable in more inferior regions above the zygomatic root and porion, and slight pitting may be found on the glenoid fossa and the petrous portion. Denser pitting and scarring are

evident toward the mastoid process where involvement is extensive. Internally, pitting is fairly dense on the inferior left parietal just superior to the squamosal suture, with pitting on the adjacent squamous temporal as well. Elsewhere on the endocranial surface of the left temporal pitting is more sporadic, and while slight pitting is present on the endocranial aspect of the right parietal, involvement of this bone is far less than on the left side. The child's severe or chronic middle ear infection may have led to its death, as otitis media can lead to meningitis (Isselbacher et al., 1994). Disease had extensively eroded the bone of the left auditory canal and invaded the mastoid air cells of the left temporal (Fig. 10a and b) and further evidence of bony involvement is seen in the pitting of the endocranial vault. Despite such evidence for bone tissue pathology, however, it does not appear that gross mastoid size was altered.

DISCUSSION/CONCLUSIONS

What then is the identity of this child from Level 8? Is it an early European Neandertal as so much of its morphology suggests, or is there evidence that this child found at the top of the Krapina sequence may have come from a different, perhaps more modern population as has been suggested previously? Given the recent dating by Rink et al. (1995, 1999) which establishes the close temporal relationship of all the Krapina deposits, the most straightforward means of answering these questions and clarifying the identity of Krapina 1 is to attempt to disprove the null hypothesis that Krapina 1 is a Neandertal and, specifically, a member of the same population as the other Krapina specimens.

Gorjanović-Kramberger (1906) considered the A Skull the most important specimen of vault from Krapina but, insightfully, focused on its young developmental age in assessing its morphology and describing how it varied from other hominids within the Krapina sample. Despite this, he considered Krapina A to be a Neandertal and steadfastly argued against the presence of any other hominid type at Krapina (e.g., Gorjanović, 1910, 1913).

Hrdlička, who produced the first English description of many Krapina specimens

(1930) following his visits to Zagreb in 1912 and 1923, was the first scholar to hint (but not directly assert) that Krapina 1 might be more modern than the other specimens at the site. Hrdlička (1930, p. 208) stated:

... the sutures are distinctly better serrated than they are in the various Neandertal crania. ... the forehead is ... fairly high, well arched, but slightly sloping, and shows faintly lateral eminences, as in white children of today. There is a shallow depression posterior and parallel to the coronal suture—as is not infrequent in modern white skulls. The postorbital narrowing is but little marked in the specimen.

However, Hrdlička apparently failed to realize that the form of the sutures and degree of postorbital constriction seen in Krapina 1 are consistent with the specimen's young developmental age at death and, as shown earlier, that its forehead falls better into the Neandertal than the modern range of variation. The post-bregmatic depression mentioned by Hrdlička, and which is also present in Skhul 1 (McCown and Keith, 1939; Minugh-Purvis, 1998), is also found in other Krapina specimens and in recent modern Amerinds (Minugh-Purvis, personal observations). Its significance, if any, remains unknown.

Škerlj (1958) was the first to unequivocally suggest that Krapina 1 provided evidence of more advanced hominids living contemporaneously with the Krapina Neandertals. Smith (1976), who reviewed Škerlj's rationale for this argument noted that:

Škerlj lists the following reasons in support of his suggestion: (1) the presence of a metopic suture, (2) the great breadth of the cranium; (3) the high forehead, and (4) the presence of advanced hominids at other sites in Yugoslavia from the same time period as Krapina.

The first of Škerlj's reasons, the presence of a persistent metopic suture, is not, as Smith (1976) pointed out, necessarily indicative of modern status as it remains patent in such Neandertals as the child from Pech de l'Azé, France. Moreover, since 1976, persistent metopism has also been identified in Krapina 20, a fragmentary adult cranium. Metopism is known to have a hereditary basis (Sjøvold, 1984) which, although variable in incidence between populations (Hauser and de Stefano, 1989), provides some argument for genetic continuity be-

tween the hominids found in different levels of the site and Krapina 1. Škerlj was correct in noting the wide breadth of the Krapina 1 cranium, which, like most metopic skulls (Bolk, 1917; Schultz, 1918, 1929; Martin, 1928; Milanesi et al., 1980), falls at the wide end of variation in the range of frontal breadth. However, it is also important to note that the great breadth of this cranium is consistent with those of other late Pleistocene Europeans and in this regard should be viewed as a regional, not a modern trait. (See comparisons of frontal breadth presented earlier and illustrated in Fig. 6.)

Škerlj's suggestion that Krapina 1 exhibits a high forehead was also examined by Smith (1976) who estimated the Krapina 1 index of frontal sagittal curvature at 89, and found it to be nearly average for Neandertal juveniles between the estimated ages of 3 and 9 years at death. In addition, Smith calculated the index of frontal curvature in a small sample of 8-year-old modern children as 87.5, only slightly more curved than Krapina 1 and consistent with the nasion-bregma index found by Minugh-Purvis (nd) of 86.1 ± 3.66 for a sample of 23 recent modern crania of mid-childhood age. As nasion must, necessarily, be estimated on Krapina 1, it is worth pointing out that comparisons of glabella-bregma index, 87.5 in Krapina 1, is slightly lower than in Neandertal children of comparable developmental age such as La Quina 18 (92.0). However, it is slightly greater than the modern mean of 86.0 mm for glabella/bregma index calculated on a sample of 6 recent modern children (Minugh-Purvis, 1988a).

The original premise for Škerlj's suggestion that a modern and archaic form of *Homo* coexisted at the site, based on his belief that modern hominids inhabited Croatia contemporaneous with Neandertals has proven unsubstantiated (Smith, 1982). Caspari (1991) and Wolpoff (1995) argued that a more modern morphology is present at Krapina itself as illustrated by the absence of a suprainiac fossa in the adult occipital specimen, Krapina 11 (Occipital 5). However, this fragment, excavated from level 8, the same level as Krapina 1, lacks the paramedian region where the suprainiac fossa, when present, occurs. Because this

area is not preserved on Krapina 11, it is impossible to assess whether a suprainiac fossa was present or absent on the specimen. Thus Krapina 11 should not be used to support the notion of a more modern morph in the highest hominid-bearing levels of the site.

Coon (1962) pointed out the presence in Krapina 1 of frontal tubers, which he described as being in the form of "a modern child." However, he did not actually label the specimen a modern human. In contrast, after studying the original A Skull calotte in the 1970s, one of us (Smith, 1976) summarized his findings by stating: "the supposed reasons for considering it modern are not specifically supported either metrically or morphologically."

Subsequent investigators, however, continued to express differing opinions with Wolpoff (1980), Minugh-Purvis (1988a), and Minugh-Purvis and Radovčić (1991), pointing out aspects of Krapina 1's morphology which are intermediate between those of Neandertals and early modern Europeans. One feature these studies have repeatedly focused on is the form of its supraorbital region. That the youthful gracility of the Krapina 1 makes it in some regards appear more modern than adults from Krapina is not especially surprising. Yet because the pattern of browridge development is now sufficiently well known (Vlček, 1969, 1970; Minugh-Purvis, 1988a,b, 1998; Smith and Ranyard, 1980; Tillier, 1987) the form of the Krapina 1 supraorbitals can be unequivocally regarded as accurately reflecting the shape, although not final size, of this feature had the child lived to adulthood. Unlike the typical Neandertal browridge, the Krapina 1 supraorbitals are differentiated into medial and lateral elements as is commonly found in early modern humans (Smith and Ranyard, 1980). Although the adult browridge specimens at Krapina do show some degree of variation, none duplicate the form of those in Krapina 1. Thus, as stated above, the so-called modern appearance of this child's browridges cannot be attributed to its youth. However a morphology similar to Krapina 1 is found in a few Neandertals, the best examples being Amud 1 (Suzuki and Takai, 1970), St. Césaire 1, and several of the Vindija specimens. It should be noted that

Krapina 1 differs from the supraorbital form seen in the Aurignacian associated Mladeč sample. The Mladeč browridges possess an extremely robust lateral element, with a midorbital arch which approaches an inverted V-shape in form. In contrast, in the configuration of its superior orbital margin, the Croatian child is clearly rounded in form as is typical of Neandertals.

Other features that have also been called into question as possibly suggesting modern morphological tendencies in Krapina 1 include the deep glenoid fossa with a well-developed articular eminence and the somewhat pentagonal form of its posterior cranial vault. However, as shown by the present investigation, both of these features are found repeatedly in other Krapina hominids and must, therefore, be recognized as part of the Neandertal range of variation. Similarly, the presence of a prominent arcuate eminence, indicative of a relatively high disposition of the anterior semi-circular canal (Williams et al., 1989), fails to point toward modern affinities in Krapina 1 given the considerable variability seen in the arcuate eminence within the Krapina sample. Despite the recent characterization of an apomorphous semicircular canal system in Neandertals (Hublin et al., 1996) the considerable degree of variation in arcuate eminence prominence seen in the Krapina collection suggests that anterior semicircular canal position also could be subject to a considerable range of variation within Neandertals. The extent to which the Neandertal range approaches or even overlaps with that of modern humans clearly merits further investigation so that the significance of variation in semicircular canal morphology can be better understood.

In 1980, Wolpoff argued that Krapina 1 should be regarded as a morphologically transitional specimen due to its possession of a more modern morphology than the specimens from lower in the Krapina deposits. In reaching this conclusion, he cited several features and proportions, one of which is the very broad cranial vault of Krapina 1. However, as we have demonstrated here and elsewhere (Minugh-Purvis, 1998, in preparation) this is a typical pattern in European late Pleistocene Neander-

tals as well as early moderns. Wolpoff also noted the presence of a high curved forehead in Krapina 1 but, this too has been shown here and previously (Smith, 1976) to fit into the Neandertal range of variation. Wolpoff (1980, p. 314) also argued that a disproportion exists between the development of the browridges and size of the cranial vault in Krapina 1, asserting "the browridges are no more developed than in very young Neandertals (ages 2–4 years)." We disagree with this assessment, as the Krapina 1 supraorbitals exhibit clear projection anterior to the frontal squama as is typical of Neandertals in mid-childhood but not seen in early childhood or infancy. No such anterior projection with a beginning posttoral sulcus is evident in such very young Neandertals as the 2–2.5-year-old Pech de l'Azé, the 3-year-old Roc de Marsal, or the 2.0-year-old Subalyuk 2 specimens. Only the Devil's Tower child, estimated to have died at approximately 4.5 years of age, shows initial development of such anterior projection, yet this is to be expected in Devil's Tower given that its permanent dental eruption had commenced. Wolpoff also maintained that the Krapina 1 vault dimensions exceed those of any Neandertal juvenile or adolescent. However as the entire vault is not preserved, it becomes necessary to examine primarily individual dimensions of individual bones which, in the present (Tables 1, 3, and 4) and previous comparisons (Minugh-Purvis, 1988a), suggest that the Krapina 1 vault in fact falls well within the range of size variation for a juvenile Neandertal who died in mid-childhood. Wolpoff (1980, p. 314) further suggested that "the size of the vault is probably a better criterion for determining age." We also disagree with this perspective, given the evidence that Neandertals followed a neurocranial growth curve quite similar to our own. Specifically the most rapid growth, and the majority of vault growth was achieved early in life (Minugh-Purvis, 1988a, 1993, 1998; Minugh-Purvis et al., 1996). The only region of the Neandertal skull that apparently grew later in development, and would thus perhaps offer a basis for observing so-called transitional vault growth, is the occipital (Trinkaus and LeMay, 1982;

TABLE 5. Characterization of morphological traits present in Krapina 1

Plesiomorphies
Short, flat parietal segment
No participation of sphenoid in internal wall of glenoid fossa
Neandertal apomorphies
Bipartite tympanic plate
Juxtamastoid eminence
Marked lambdoid flattening of posterior parietals
Intermediate between Neandertal and Early Modern form
Pinched lateral browridge element
Regional European traits
Wide frontal

Minugh-Purvis, 1998, in preparation). However, the Krapina 1 occipital is not intact and so is not available for comparison with other late Pleistocene children.

Recently, Wolpoff (1999) has reiterated the possibility that Krapina 1 might represent a morphologically transitional specimen between clearly Neandertal specimens at Krapina and more modern late Pleistocene Europeans, but now bases this solely on aspects of frontal morphology, specifically supraorbital size and form and forehead vaulting and breadth.

While we do not completely reject the hypothesis that such morphology theoretically could reflect a transitional pattern, we do not believe that such an hypothesis is the most parsimonious one in this case. Rather than focus on the single exceptional aspect of Krapina 1's morphology, its unusual browridge, we have attempted here to concentrate on evaluating what is preserved of the child's total, overall morphological pattern. In doing so, this study serves to further illustrate the considerable degree of variation to be found in the late Pleistocene Europeans known as Neandertals, including often difficult to discriminate differences between those people and early members of modern *Homo sapiens*. The ontogeny of most of the traits examined here (see Table 5) is now sufficiently well known in late Pleistocene populations from this region of the world to anticipate their adult form and to understand the significance of their morphology in an immature state.

Summary examination of Krapina 1's morphology reveals plesiomorphous traits, such as the presence of a short parietal segment and a lack of participation of the sphenoid in

forming the internal wall of glenoid fossa, which argue against a modern status for this individual. On the other hand, Krapina 1 shares several significant features, specifically its rounded superior orbital margin, pronounced lambdoid flattening, bipartite tympanic plate, juxtamastoid eminence, and presence of Brechet's sinus, with European Neandertals. Its large frontal breadth is perhaps best regarded as typically late Pleistocene European. Other features, such as the form of the glenoid fossa, mastoid size and shape, external auditory meatus form, and degree of arcuate eminence relief, fall outside of the range currently known for western European Neandertals. However, all occur elsewhere within the Krapina sample, with the exception of a browridge form more typical of late Neandertals and early modern *H. sapiens*. That the Krapina 1 browridges are not typical of such an early Neandertal illustrates the importance of further studies into the development and functional morphology of this feature. That Krapina 1 exhibits such a mosaic of features further underscores the fact that Neandertals are not as morphologically homogeneous as often portrayed in the literature. This is perhaps the most important lesson Krapina 1 teaches. Despite its mosaic pattern, the metric and nonmetric characters of Krapina 1 examined here in comparison with other late Pleistocene hominds, as well as recent modern children, reveal a total morphological pattern strongly supporting the contention that Krapina 1 derives from a European Neandertal population.

ACKNOWLEDGMENTS

We are deeply indebted to many individuals throughout Europe who made it possible for one of us (NM-P) to collect the comparative data on immature late Pleistocene remains and to Dr. Mark Skinner for comparative recent human metric data. Also, we thank those who, together with us, have contributed to the restoration of the Krapina 1 specimen in recent years: Mary Russell, Milford Wolpoff, Rachel Caspari, and Tim White. We also thank Doug Purvis and Dražen Pomykalo for photographs, and Krešimir Čavka for radiographs of the specimens indispensable for this study. Finally,

we express our gratitude to the directors of the Croatian Natural History Museum who have permitted us to undertake this work over the years: Nikola Tvrković, Kretchmer Sakač, and our beloved friend and teacher, the late Ivan Crnolatac.

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